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ABSTRACT

The theme of the Association for the Development of Computer-Based Instructional Systems (ADCIS) 1994 conference was "New Partnerships: People, Technology, and Organizations." Included in the 38 papers and abstracts compiled in this document are the following topics: hypermedia; the National Research and Education Network and K-12 schools; computers in education; educational technology; problem-solving; computer-assisted learning systems; computer graphics and motivation; computers and developmental disabilities; interactive video; the Internet; instructional design; computer simulations and problem-based learning; intelligent tutoring systems; ergonomics; and electronic performance support systems. (JLB)

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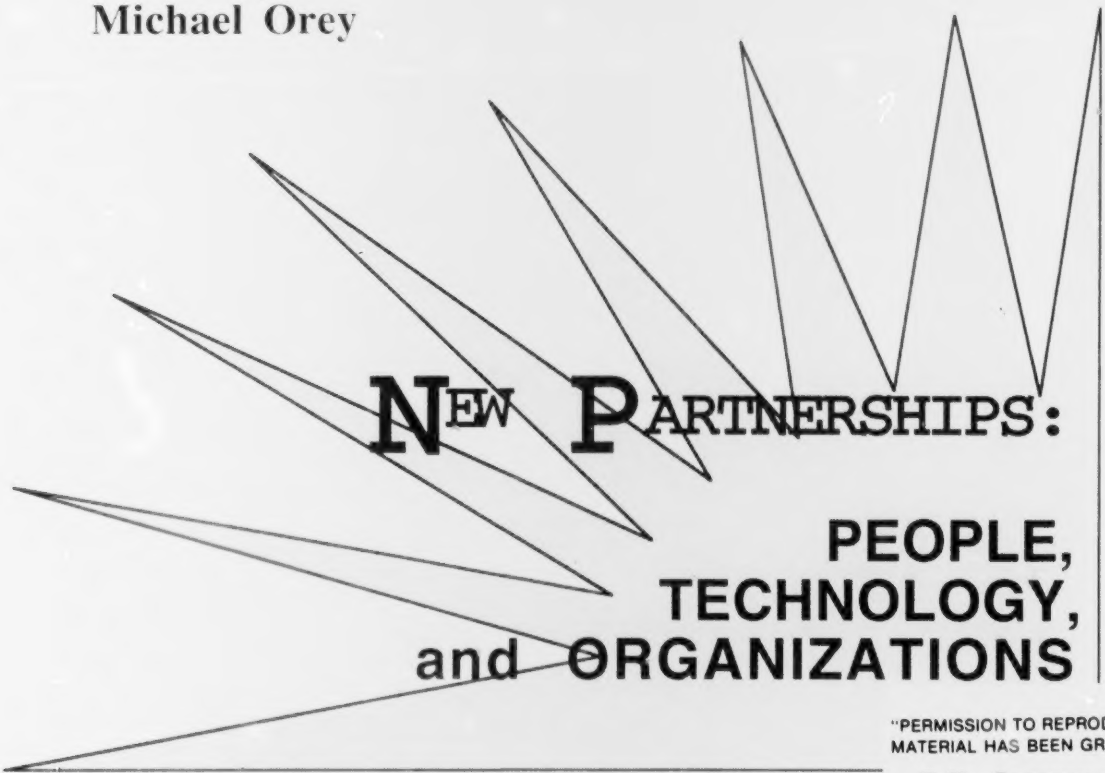
Proceedings of the Thirty-Fifth International ADCIS Conference

ADCIS

Edited by:
Michael Orey



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PEOPLE, TECHNOLOGY, and ORGANIZATIONS

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ADCIS

The Thirty-Fifth ADCIS Proceedings

Association for the Development of Computer-Based Instructional Systems

Opryland Hotel
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Stephen, M.L. (1994). First graders, hypermedia and creativity [Abstract]. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (p. 1). Nashville, Tennessee: Omni Press.

First Graders, Hypermedia and Creativity

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In 1989 a partnership was established between Harris-Stowe State College, a historically black teacher education institution, and Waring Academy of Basic Instruction, a magnet school in the St. Louis Public Schools. In 1992, the computer education instructor at the college and a first grade teacher at the magnet school initiated a project to introduce a hypermedia package to the first graders and to explore ways to integrate use of the program into the first grade curriculum. Only three of the 23 students in the original group of first graders had access to computers outside of the school setting. The project included use of the one computer in the students' classroom and weekly visits to a computer lab at the college. The original goals of the project were to determine whether first grade students could learn to use a hypermedia authoring system in a meaningful way, to determine if using such a program enhanced the first grade curriculum, and to determine any benefits from using such a software package with first graders.

The results of the first year of this project were extremely encouraging. The students mastered the software package much more quickly than anticipated. Students learned to create stacks which incorporated original artwork, text, clip art, original sounds, clip sounds, visible and invisible buttons, card transitions and text items. Lack of initial reading skills did not hinder the students' ability to learn the package. Students were taught keyboard commands for the basic actions, thus eliminating the need to read items in menus. Curricular areas which appeared to be positively impacted by this project include reading, language arts, math, science, social studies and art. In addition, the level of cooperative learning was outstanding. Students often referred to their computer experiences to help them solve problems in the more traditional classroom setting. The first grade teacher, a 33 year veteran, indicated that she had never observed such a degree of self-confidence among first graders before. The teacher also noted that there appeared to be a definite transfer effect in the students' sequencing, reading, spelling, writing and fine motor skills, as well as creativity level.

The project is currently in the second year, with a new class of first graders now participating. The students involved this year share many of the characteristics noted previously in the original class of students. Students have already learned more features of the package than students involved in the first year of the project, a fact the teachers involved attribute to their initial fear that they would overwhelm the students if they presented too many features. Observations from the previous year have convinced them otherwise. Once again all students involved exhibit the ability to work well cooperatively, and the same high level of self confidence observed in the students in the first year of the project.

Cook, C. W., & Clariana, R. B. (1994). Kids get the good stuff: A progress report on Jostens Learning's networked interactive multi-media mathematics project [Abstract]. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (p. 2). Nashville, Tennessee: Omni Press.

Kids get the good stuff: A progress report on Jostens Learning's networked interactive multi-media mathematics product

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Jostens Interactive Multi-Media (IMM) is a k-6 curriculum in mathematics and language arts utilizing full-motion interactive video delivered over a local area network. Units include individualized and small group activities both on-line and off-line, and on-line teacher demonstration and presentation activities. The software will be delivered in stages. The first portion to be released in the summer of 1994 is called "Teacher First" and consists of the teacher presentation and demonstration activities in mathematics. We will present several of these activities today and allow time after the session for you to have hands-on with the demo unit. Because of the limited time available, most of the presentation will focus on Teacher First, though we will address some issues regarding IMM.

Teacher First was designed to be a low-cost, entry level product. It runs stand alone utilizing either MS-DOS or Mac machines. The MS-DOS machine requires at least a 486sx/33MHz, 12MB RAM (16 MB for Capture/Edit), 80 MB hard drive (1 GB for Capture/Edit), CD-ROM, ActionMedia II Card, VGA monitor, DSP 301 Audio/Ethernet card, and CS2 Capture Card. The Mac machine must be either an LCIII or Quadra, 12MB RAM (16 MB for Capture/Edit), 80 MB hard drive (1 GB for Capture/Edit), CD-ROM, and New Video EYE-Q video card. Teacher First software can also run over the Jostens Learning Multi-Media File Server.

The instructional design is a direct implementation of the NCTM standards and utilizes methodological constructivist ideas. Specifically, the activities address mathematics concepts within theme-based units or contexts (rather than as isolated skills). The software is thus only one component of the total learning environment. Accompanying instructional materials include a teachers' guide with detailed lesson plans. A typical unit involves "center" activities where kids work together on assigned tasks in small groups. Centers include manipulatives, games, and other types of activities.

Ease of use is a critical instructional issue when using multi-media applications in the classroom. The software interface is a unique and simple part of Teacher First. Alpha product testing has shown that even naive mathematics educators can utilize the interface optimally after even a brief exposure.

To summarize, Teacher First brings together all of the current threads in mathematics education into one complete, easy to use application. This may be an evolutionary product that changes the way teachers teach as well as the way students will learn.

Baker, L. M. (1994). Putting the "E" in NREN: Implications of connecting K-12 schools to the information superhighway [Abstract]. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (p. 3). Nashville, Tennessee: Omni Press.

Putting the "E" in NREN: Implications of Connecting K-12 Schools to the Information Superhighway

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The National Research and Information Network (NREN), the "information superhighway" proposed by national legislation, holds great promise for K-12 schools. Yet there are major technical, economic and structural obstacles to overcome to realize that promise, and often unexamined legal, cultural and social impacts of connecting schools. The methods of technology assessment can be used to systematically explore the obstacles and impacts so policy decisions can be made which will help K-12 schools determine what is desirable, as well as realize what is possible.

The presentation considered three major questions related to school networking, borrowed from McClure, Bishop, Doty and Rosenblum (1991).

(I). How can the use of electronic networks facilitate the tasks and goals of particular communities of users?
(II). What problems do particular communities of users face in attempting to exploit networks for accomplishment of those tasks and goals?
(III). What design, management and policy strategies can alleviate those problems and maximize network use and effectiveness?

These three questions were addressed considering the special needs of K-12 educators and students as the community of users. Extensions of NREN to the K-12 community means that an 'elite' medium of scientific communication and collaboration becomes more a 'mass medium' by connecting many more users of a diverse kind. It also means connection of children, a protcted group with special developmental needs, to a largely adult medium. What implications do these changes have for schools?

Why technology assessment?

Technology assessment (TA) arose as a field of study in the 1960s and 70s to help systematically consider the impacts adoption of a particular technology might have for society as a whole **before** the technology was widely adopted. Environmental impact assessments are the most widely recognized and often practiced form of technology assessments.

Not many professionals interested in educational technology are aware of the formal methods of technology assessment, yet some of these methods could be productively used to address educational technology issues and give focus to policy debates. The presentation introduced participants briefly to a few of the techniques of TA to illustrate how TA can help answer some major questions in our field, as well as raise different **kinds** of questions not always considered in the rush to adopt whatever is newest. If K-12 educators wish to influence national telecommunication policy, such as NREN, then it would be helpful to know in which directions their best interests lie, something TA can help them determine. TA can also outline new areas for research, as the process often points out areas where empirically-derived information is either lacking or inadequate.

Participants were given a four page bibliography on technology assessment, its methods and relevant studies.

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Shaffer, C. A., Begole, J.M.A., & Carstensen, L.W. Jr. (1994). GeoSim: A GIS-based simulation laboratory for introductory geography [Abstract]. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (p. 4). Nashville, Tennessee: Omni Press.

GeoSim: A GIS-Based Simulation Laboratory for Introductory Geography

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We demonstrate three modules currently under development for **Project GeoSim**, a multidisciplinary effort by members of Virginia Tech's Departments of Geography and Computer Science, College of Education, and Learning Resources Center to develop computer-aided education (CAE) software for introductory geography and related classes. **GeoSim** modules are designed to teach students the concepts of dynamic geographic processes through interactive exploration. The modules combine the information presentation and analysis capabilities of Geographic Information Systems (GIS) with interactive techniques of computer simulation. Through a multidisciplinary approach aimed solely at educational needs, we automate the use of GIS and simulation so a full understanding of spatial and statistical analysis techniques is not a prerequisite to learning from them.

GeoSim modules will become part of existing comprehensive courses without relying on instructors to modify their courses to "fit them in," or worse to buy expensive equipment on which to operate them. The modules fit closely into existing models of introductory geography as illustrated by current popular texts. The modules will run on IBM compatible 80x86 machines, Macintosh II computers, and UNIX systems running X-Windows.

All **GeoSim** modules share the same menu-driven interface. In general, the modules begin with a multimedia tutorial presenting the information to be learned, followed by a simulation to allow the student to actively use the information.

The three modules to be presented are as follows.

International Population allows students to investigate the effects of altered birth, death, and net migration rates on the population pyramids and total population levels for any country or region in the world. The simulation supports comparison of two countries simultaneously, and permits three different scenarios to be displayed at one time for each country.

Modeling of Migration in the United States relates county migration patterns in the U.S. between 1950-1990 with data on place characteristics. Students will be asked to select and weight push and pull factors to model migration patterns. They will learn about the scientific method by making hypotheses regarding effects on migration patterns and then immediately testing these hypotheses.

Mental Maps is a simple graphical quiz program that tests students' knowledge of the location and characteristics of cities by having the student point to a position on an outline map drawn on the computer screen and then answer a series of questions. After the student selects city placements, a "mental map" showing the student's perception of the geography of the country is generated and displayed.

GeoSim modules are available through anonymous FTP or gopher at "geosim.cs.vt.edu."

Thompson, C., & Thompson, D.E. (1994). Technology and the family: Incorporating education into home economics education [Abstract]. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (p. 5). Nashville, Tennessee: Omni Press.

Technology and the Family: Incorporating Technology Education into Home Economics Education

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The Carl D. Perkins Vocational Education Act mandates that technology education be included in home economics instruction. New curriculum is being introduced into the home economics classroom to help secondary students understand the interdependence of technology and family life. To prepare future teachers for these curriculum changes, all home economics education students at the University of Arkansas are required to become familiar with general and educational uses of the computer and learn how to create an awareness of how new technological innovations affect family life.

Students are required to use word processing, data base and spreadsheet applications as well as home economics courseware. For teacher assistance, they use word processing to write lesson plans and professional resumes, data bases to develop test question banks for multiple choice tests, organize inventories and maintain student records, and spreadsheets to plan budgets and determine grades. Courseware is integrated into nutrition, consumer education, housing and clothing classes. For classroom applications, students learn to incorporate tutorials and simulation software into lessons, use nutritional analysis software to analyze the adequacy of diets, use design software to plan spaces and garments, as well as use application software to help learners explore personal and family finance. Draw software is used to encourage students' creativity. Desktop publishing is used to create flyers and brochures for the student member section of the American Home Economics Association. With the assistance of the technology education instructor, students are introduced to robots and their use in home and industry.

Students plan technology-related lessons using activities in Impact of Technology on the Family (Segraves, Carrick, Pence, Brixey, James, Knight, Gregory & Kellner, 1992). Some examples of lesson objectives are evaluating technology used by children, determining technology to solve family problems, evaluating how technology will affect future jobs, evaluating the ethics of the use of technology in the medical field, and designing technologically based products for the home. Students also evaluate technology used in household equipment such as microwaves, small kitchen appliances, home computers, video games, stereos, televisions and photo compact discs.

Home economics education students receive a minimum of twenty hours of direct computer instruction in four home economics education classes as well as individual assistance with personal and class projects. Students also plan computer related projects during students teaching using equipment found in the secondary schools.

Students work with Macintosh, IBM, and Apple IIe computers to prepare them to use the equipment they will find in secondary classrooms and computer laboratories. They are also introduced to CD ROM and interactive video technology.

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Aj.am, M. (1994). Impact evaluation of a CBT program developed to increase the effectiveness of law enforcement and prevent police civil liability [Abstract]. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (p. 6). Nashville, Tennessee: Omni Press.

Impact Evaluation of a CBT Program Developed to Increase the Effectiveness of Law Enforcement and Prevent Police Civil Liability

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Abstract: A CBT project has immediate and long-term objectives. Immediate objectives are related to the mastery of the learning material and this can be accomplished within the time-frame of the training program. Long-term goals are related to the ultimate impact of the CBT program and cannot be accomplished until some time after the completion of the training program. This paper examines the long-term impact of a CBT project developed to increase the effectiveness of law enforcement and prevent police civil liability.

Losses from police civil liability cases averaged $800 per officer in 1987. An effective way to prevent court judgments for civil liability is to prevent illegal mistakes by the officers on the street through continuous training and testing of officers on the correct legal way to do the high risk tasks of police work.

MIRMA is a non-profit self-insurance pool that covers 60 cities in Missouri. It insures the towns and municipal utilities against all claims made as a result of the official actions by all their employees. About 16% of the employees of the member governments are police (1250 officers.) Throughout the early to mid 1980s, losses for claims of misconduct by police had escalated at the national rate. In 1989, MIRMA instituted a proactive loss preventing program for police activities. As part of this program, MIRMA contracted with the Police Law Institute to provide monthly computerized legal training to all sworn personnel of the 60 member municipalities.

Within a year, the impact of this continuous training became apparent. While the national insurance rates for police liability have continued to increase, the cost of liability for MIRMA cities has declined: (1) The losses have declined each year that the training program has been in effect.; (2) From fiscal years 1989 to 1991, the cost of losses, on a per-officer basis, had declined 66%. The cost of losses for 1989 were three times those of 1991; and (3) When the effects of price inflation, the reduction is even more dramatic. MIRMA's projections show that without the loss prevention program, the per-officer losses in 1991 would have been five times greater than the amount that they actually incurred.

One of the other long-term objectives of the Police Law Institute's computer-based training program is to increase the effectiveness of police work. This implies more successful conviction of criminals and reduced crime rate. These are two long-term goals that have not been evaluated yet, partly because of the difficulty in gathering the necessary relevant data.

Campbell, J.O. & Lison, C.A. (1994). New strategies for learning and performance assessment of interpersonal problem-solving skills. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 7-10). Nashville, Tennessee: Omni Press.

New Strategies for Learning and Performance Assessment of Interpersonal Problem-Solving Skills

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Abstract: In a world of global competition, the ability to collaborate to solve problems is critical. However, learning such skills can be difficult and expensive. Strategies that use simulations can be helpful for technical training, but we lack strong evidence of the effects of similar methods for interpersonal problem solving. This paper discusses two experimental studies that address these issues. The studies used both hard (computer and video) and soft (instruction design) technologies. Experiment 1 kept the instructional methods as similar as possible, but cut instructor time by 50 %, by substituting computer tutoring and skill modeling on video for corresponding methods in the classroom. The computer and video group performed as well as the classroom group. Experiment 2 cut instructor time by 67% using similar substitutions, and also optimized the methods, using video recording and small group feedback on individual performance. It found significant improvement of subjects' performance in the optimized group over the classroom group.

We live in a world where global competition places a premium on collaborating on problem solving. Working with another person to solve a problem is one of the most critical skills to master and yet one of the most expensive to instruct, because it requires expert modeling and coaching. The limited availability and high costs of experts limits access to such skills. Computer-based instruction by itself is of limited help because problem solving interactions are ill defined. In addition, computer hardware and software has very limited ability to understand spoken discourse and intonation, or to interpret visual cues such as body posture. We must work out combinations of instructor, students, and technology to deal with these issues.

Much of our current instruction yields what Whitehead (1929) terms inert knowledge that is not used when the need arises. Learners must learn how to perform in complex situations, and also how to learn on their own to perform. Performance-based simulation is a powerful strategy for situating learning in contexts that are like those where learners will use the skills. By controlling the complexity and adding coaching and evaluative feedback, the simulation may become a learning situation and an assessment

Campbell, J.O. & Lison, C.A. (1994). New strategies for learning and performance assessment of interpersonal problem-solving skills. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 7-10). Nashville, Tennessee: Omni Press.

tool. Using similar coaching, the system may also become a job aid/performance support tool.

Problem: Cost

There is a problem, however: cost. A method that uses lecture to "cover the content," followed by multiple choice tests is typically far less expensive to develop and deliver to large numbers of people simultaneously than is individually coached and assessed performance development. The cost is lower, although the benefits may not be as great.

There are several possible responses to this issue that may either increase productivity or decrease costs:

1. Use computer and other simulations that successively increase the level of challenge to the learner (e.g., micro-worlds and the graduated length ski method discussed by Burton, Brown, and Fischer, 1984)
2. Use evaluative feedback in the simulations (Gibbons & Rogers, 1991)
3. Use the simulation for both learning and assessment, thus sharing the costs (e.g., Frederiksen & White, 1990; Bunderson, Olsen, & Greenberg, 1992; Campbell, 1992)
4. Use the simulation for performance support when the skills are used (Campbell, 1992)
5. Use computer-aided instructional design tools (e.g., Pirolli, 1991)

Most of the prior work on learning simulations has been for technical skills on complex, expensive, or dangerous equipment. In these cases the cost savings can be very high in relation to purchasing actual equipment for training purposes (for example, an airplane, a telephone exchange, or a radar system).

In this paper we discuss the extension of simulations having some of the above properties to interpersonal skills. We note that these simulations use students, the instructor, computer, and video. We also note that performance support may come at low cost if it is already part of the coaching component of an evaluative simulation.

The Problem Solving With Others Study

There is some promising research in the area of interactive training for "soft skills" Cronin & Cronin (1992). The research methodology of the original studies was often questionable, however, given the difficulty with assessing interpersonal skills. To extend the line of research, our group conducted two studies, each with a two-group experimental design.

The first study contrasted a classroom lecture/discussion/small group method with a similar method that used computer and video. We used the computer and video vehicle where possible to help students learn certain skills and to see the skills modeled. By doing so we cut the amount of instructor time in half for the same level of performance, but kept the methods as similar as possible.

Campbell, J.O. & Lison, C.A. (1994). New strategies for learning and performance assessment of interpersonal problem-solving skills. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 7-10). Nashville, Tennessee: Omni Press.

In the second study we optimized the combined instructor/computer/video treatment, in which small teams practiced together. For both groups we created a scoring instrument that would capture a circumscribed set of skills related to facilitating problem solving by another person. We have validated the interpretation of this instrument by using outside blind raters, who did not know what treatments were used or who was assigned to each treatment.

A classroom treatment used lecture-discussion, modeling, role play, and small team interactions, with the instructor facilitating each activity. A combined instructor and technology treatment used computer tutorials and modeling on videotape to supplement the instructor's similar learning activities.

Both treatments required nine hours of subject time in the first experiment and six hours in the second experiment. Subjects were tested in a videotaped role-play. In the combined instructor and technology treatment we decreased instructor time by 50% in Experiment 1, and by 67% in Experiment 2. In Experiment 1, our analysis indicated that the combined group scored as well on the posttest as the classroom group. In Experiment 2, the optimized group showed significant gains, but the classroom group did not. An independent rating by three counseling students, who were blind to the experimental treatments, also found a significant difference on the posttest favoring the group using the combined treatment.

This research has borne fruit: We found ways to use small teams of learners with relatively low technology simulation tools (e.g., computer tutorial and videotape modeling of skills) to yield significant time savings and increased student performance over the traditional classroom method. This work is reported by Campbell, Lison, Borsook, Hoover, and Arnold (in press). From the studies noted above, we find support for the hypothesis that treatments using technology-supported methods can decrease the amount of instructor time needed to learn interpersonal problem solving skills, while achieving results comparable to a fully instructor-led learning experience using similar methods.

Campbell, J.O. & Lison, C.A. (1994). New strategies for learning and performance assessment of interpersonal problem-solving skills. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 7-10). Nashville, Tennessee: Omni Press.

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An Analysis of A Computer Assisted Learning System: Student Perception and Reactions

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Abstract: Within Mathematics of Finance classes at the Smeal College of Business Administration at Penn State University, lectures are developed using Asymetric's Toolbook and are presented via a computer system. This approach was implemented because it has the potential to effectively convey concepts that are ordinarily difficult to communicate to large classes of students. For example, the class can input arbitrary interest rates and instantly see their effect on other variables.

In the fall semester of 1992, an analysis was conducted on a class of 58 junior level Actuarial Science students. The methods used to make this analysis were to video record all class lectures with two video cameras. One camera focused on the students and collected their physical reactions such as facial expressions and body movements and the second camera recorded images projected by the computer system. Students also received a pre and post attitude survey to collect their perception of the computer-assisted lectures.

The Smeal College of Business Administration at the Penn State University continues to investigate the potential of computer-assisted learning systems. Within Mathematics of Finance classes, lectures are developed using Asymetric's Toolbook and are presented via a computer system. This approach was implemented because it has the potential to effectively convey concepts that are ordinarily difficult to communicate to large classes of students. For example, arbitrary interest rates can be fed to the system and students can instantly see a visual representation of their effect on other variables. The instructor can ask questions and input student responses and electronically graph the result during lectures to help monitor the classes' attentiveness or understanding of the material. This approach adds additional dynamics to lectures and assignments.

While it seemed, from an instructor perspective, that the computer-assisted learning approach could positively impact classes, it was unclear as to how students would react to it. A pilot study was therefore conducted to collect student perceptions and reactions to this instructional approach. The objectives were to make an initial assessment of the computer-assisted lecture delivery format; to collect student reactions to this delivery format; and to investigate the potential of video recording as a method of data collection because, among other things, videotaping has been used extensively for subject observation with substantial benefits reported (Baum & Gray, 1992).

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Methods

In the fall semester of 1992, an analysis was conducted on a class of 58 junior level Actuarial Science students. In previous years, the general characteristics of the classroom were as follows: each student had a copy of the professor's typed notes upon which they wrote comments; the professor knew each student by name; an attempt was made to call upon each student at least once each class to respond to question related material; and an important part of each lecture was explaining concepts to the "man on the street." The change this semester was that lectures were presented via a computer systems using Toolbook.

There were two methods of analysis used. One method was to video record all class lectures. For video recording, the researchers used two cameras. One camera focused on students to collect their physical reactions such as facial expressions and body movements and a second camera recorded the visual images projected by the computer system. The researchers later combined the video signal so that physical reactions could be seen simultaneously with what was projected electronically by the computer. Thirty-two 75 minute class lectures were recorded of which 7 are examined in this paper. For analysis, non-verbal communications as well as classroom interactions were examined relative to the delivery format.

The second method used to assess the impact of this technology was an attitude survey. In week one of class, students were given an introduction to computer-assisted lectures and informed that throughout the course, lectures of this type would be given. At the end of the first week, students received a pre-attitude survey .

A post-attitude survey, identical in nature to the pre-attitude survey, was given in the last week of class. The researchers compared surveys to observe if any differences occurred in attitude toward the computer-assisted lectures from the beginning of the semester to the end.

Each survey presented statements to which respondents rated their reactions on a 9 point scale from 0 to 8. The scale ranged from Strongly Agree (0 points), to Indifferent (4 points), to Strongly Disagree (8 points). Of the 58 students who completed a pre-attitude survey, only 31 completed a post-attitude survey. The analysis of survey data is, therefore, based on 31 respondents.

Results & Discussion

Videotaping method

Video recording class lectures appears to have potential merit in monitoring student reactions to new technological approaches in the classroom. The video medium provided a permanent record of students and how they responded to the computer-assisted lectures. Numerous observations could be made specifically about the technology, as well as the class in general, and these observations could be reviewed repeatedly and verified by others.

Video recording lends itself to the collection of large amounts of various kinds of data, which requires more time, effort, and resources to analyze. The advantages of this technique relative to cost need to be more thoroughly investigated. At present, however, the video recording approach as presented in this study appears to be an effective method for identifying student reactions to computer-assisted lectures.

Videotaping results: classroom interaction

For this analysis, tapes from five class sessions were reviewed. The researchers look at the following classroom interactions:

- areas to which the majority students directed their attention (e.g., professor's typed notes, the professor or the projected image) in response to the computerized lectures;
- areas to which the majority students directed their attention in responses to type of visual images projected (e.g., graphs).

Computerized lectures can, in many cases, take significantly longer to develop than traditional lectures. Because of this time and labor intensiveness, it is important to ensure that the visual information

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projected effectively cues students and is useful to them. By making observations, the researcher hoped to improve the presentation material by identifying screens designs which caught student attention and designs to which students responded favorably.

To determine whether or not screen designs effectively cued student attention, the researchers counted each time the majority of students look up or looked down in response to what was projected by the computer. Four categories were created:

1. No visual and looking up
   The number of times the majority of students were looking up when no visual was projected by the computer.

2. No visual and looking down
   The number of times the majority of students were looking down when no visual was projected by the computer.

3. Visual on and looking up
   The number of times the majority of students were looking up when a visual was projected by the computer.

4. Visual on and looking down
   The number of times the majority of students were looking down when a visual was projected by the computer.

If the purpose of presenting visual information via a computer system is to promote, in some way, student understanding, then it becomes important to ensure that the visual effectively conveys its meaning and that students attend to it. The primary reason, therefore, for identifying these categories was to determine, in a general sense, if students viewed the visual information when it was presented. The highest incidences occurred in the visual on and looking down category (see Table 1).

Table 1
Response to Visuals: Attention Areas

	Class 1	Class 2	Class 3	Class 4	Class 5	Total
No visual & looking up	15	0	12	1	3	31
No visual & looking down	10	0	7	13	0	30
Visual on & looking up	9	15	2	19	13	58
Visual on & looking down	16	14	8	22	18	78

This means the there were 78 incidences when the majority of students were looking down for the period of time when the visual was projected. It should be pointed out that students had the professor's typed notes with which to follow the lecture. Thus, it is to be expected that they would page through these notes while the concept was discussed. Oftentimes the professor talked through visuals using the computer mouse to point out key areas and formulas. Frequently during this time, a large portion of the class referred to the professor's notes and paged back and forth through them. It appeared that, among other things, the notes enabled students to bring together additional information that may or may not have been presented on screen. The reliance on the notes seems to provide an additional means by which students individually verified the presented information and or came to understand it.

Given the value of the projecting visual information for the entire class to view and the way in which students, during class lectures, utilized the professor's typed notes, it is difficult to assess the effectiveness of screen designs. A future inquiry might include a control group which is presented the visual information unaccompanied by the professor's notes to more accurately identify student reactions.

Videotaping results: reactions to visual types

The researchers wanted to identify the types of visuals (text, animated graphs or tables) which most effectively cued student attention. It appeared that students looked down or took notes when visuals containing text and formulas were presented. On most occasions, however, when the professor presented graphs containing animations, students looked up. Two reasons are suggested this observation. First, the professor's typed notes contained formulas and replicated what was present on screen and thus there may have been no need for students to look up. They could easily follow the professor by looking at his typed notes. Second, unlike text and formulas, animated tables and graphs can not be duplicated on paper. Animation may have received more attention because of its distinctiveness. Animation as an attention gaining device can be effective since attention is influenced by unique stimuli. Possibly, animating tables and graphs was unique enough to gain students' attention.

General observations:

Video recording made additional observations about the class possible and some of these observations are presented below.

- For five of the class sessions, the number of student initiated interactions with the professor were recorded. Each time a student commented or asked a question, it was considered an interaction. If a student, for example, asked a question and then followed up immediately with a second question, then it was counted as one interaction. There were 83 occurrences when students initiated interaction with the professor, 32 of which were initiated by males and 51 by females. Such information may prove useful to the professor since classroom interaction among all students was highly encouraged.

- Cueing students with key words is attention getting. Students, as observed in this study, spent much time following along with paper handouts and often ignored what was projected on screen. For example, when the professor said, "I have a picture here." students looked up, and on subsequent occasions the word "picture" appeared to get their attention.

- Much can be gained from observing students and watching their body language and reactions. In some cases an observer can readily tell when students do not understand or are confused (Alessi & Trollip, 1985). Throughout the course the professor constantly challenged students by posing questions. Students often displayed behaviors like smiling or looking downward when they did not know the answer. It was also clear by viewing the video tapes when more than one student was having difficultly with a concept or question. In such cases students looked to one another, shook their head or made a facial expression.

Attitude Survey Results

On a survey, subjects ranked the number of computer courses they had completed on a 10-point scale ranging from 0 to 9 or more completed courses. Completed computer courses was used as a measure of computer knowledge (Rattanapian, 1992). The researchers obtained this measure to determine if knowledge

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about computers influenced perceptions of the lectures. On average, students completed 2 computer courses. Figure 1 shows the percentages of respondents by number of courses completed.

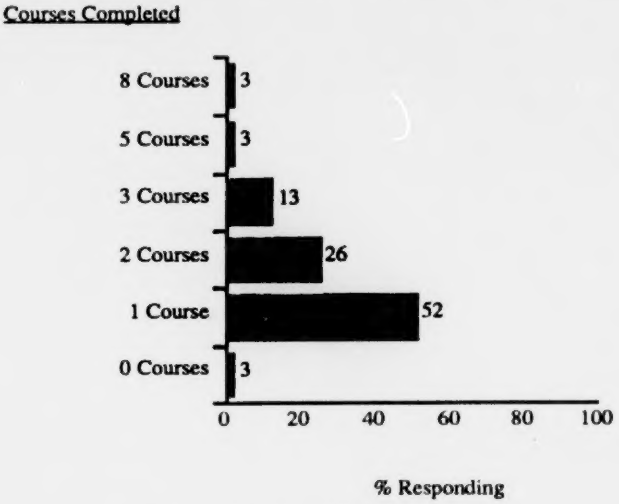

Figure 1. *Computer Courses Completed*

Given the proliferation of technology in today's classrooms and the use of computers to present information electronically, the researchers sought to identify the extent to which students in this class had been exposed to computerized lectures. On the pre-survey, students ranked their experience and on average reported having no experiences with the lecture format. (see figure 2).

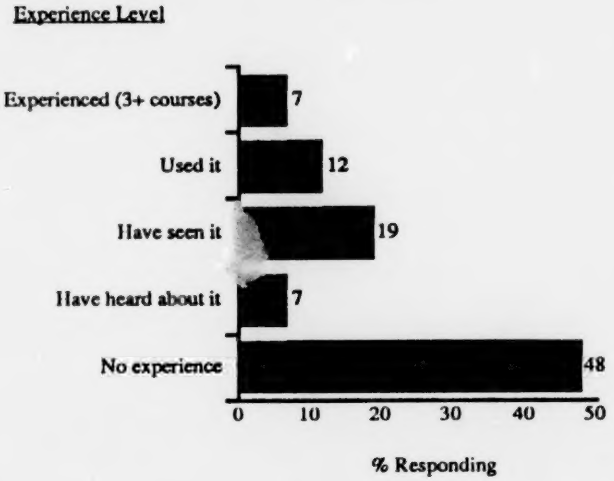

Figure 2. *Experience with Computer-Assisted Lectures*

Despite the lack of exposure, students anticipated that the computer would not make lectures more complex (see figure 3). On the survey, for example, students were asked if they thought the computerized lectures would be easy to follow. Responses to this item were positive and this perception remained constant from the pre to the post survey.

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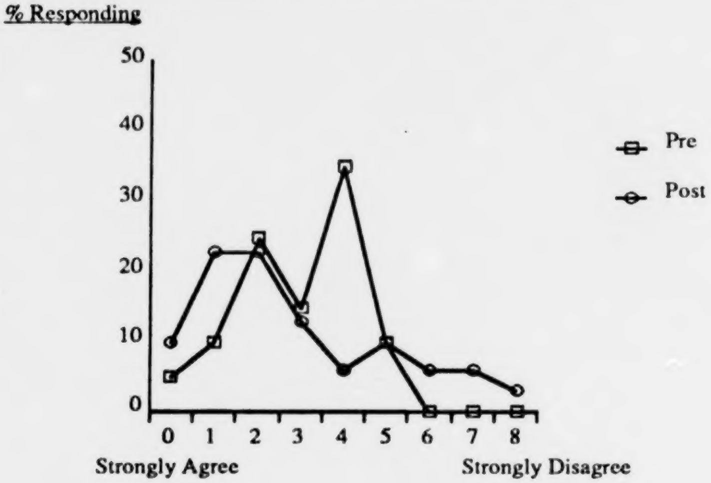

Figure 3. *Lectures were easy to follow pre and post surveys*

Students anticipated that the lectures would be informative (see figure 4). On the survey, students were presented the following item, "Computer-assisted lectures will be informative." Responses tended to be on the positive side and this perception remained constant throughout the semester.

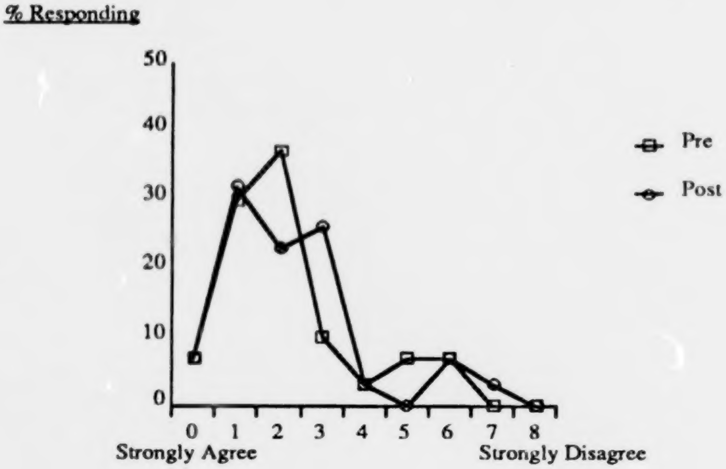

Figure 4. *Lectures were informative pre and post surveys*

Computer familiarity and attitude

Classroom computers are neutral in design but lack neutrality often times in the way they are used (Jones, 1987) and perceived. Males, for example, have been found to readily express interest in computers while females are less likely to do so (Miura, 1987). Students in this study had varying levels of computer

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expertise ranging from novice to experienced users. The researchers were interested in determining if computer familiarity effected (positively or negatively) students' attitude toward lectures. As a measure of familiarity, number of computer courses completed was used based on the assumption that some familiarity with computers is required with course completed. Familiarity did not appear to negatively bias students' opinion of lectures and in fact, students appeared to look forward to the teaching format.

At the beginning of the semester, in the pre-attitude survey, students were asked if they thought the lectures would dramatically impact the way in which the course was taught. Responses, examined in terms of computer familiarity, show that for some respondents the perceived degree of impact of the computerized lectures decreased as the number of computer courses completed increased (see figure 5). Thus, those having completed more computer courses felt that the computerized lectures would have less of an impact than those with fewer courses. This may suggest that those with more courses completed understand the technology and its limitations to a greater extent than those with fewer courses. It should be pointed out, however, that only 7 students completed more than 3 courses and the majority of respondents completed fewer than 2 courses. From such a small sample, it is difficult to assess whether or not this trend would persist for larger populations.

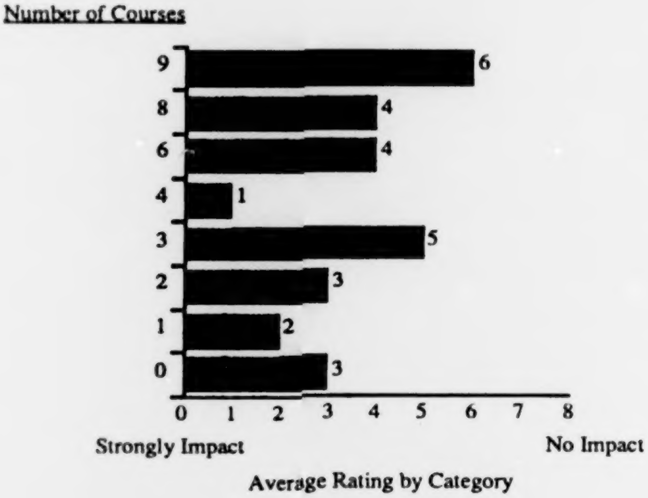

Figure 5. *Perceived Impact by Number of Computer Courses*

On the pre-attitude survey, students indicated whether or not they would feel comfortable being taught with computerized lectures. For this analysis, there were 15 out of the 32 respondents who had completed fewer than 3 computer courses and they indicated that they would feel comfortable being taught with computerized lectures (see figure 6). Of these 15 respondents, fewer computer courses completed coincided with favorable ratings. There appeared to be a tendency for those who had completed fewer courses to indicate that they would feel comfortable being taught with computerized lectures. Again, because of the lack of distribution of students across the different levels of courses completed, it should not be concluded that those with more familiarity would feel uncomfortable being taught with computerized lectures. On the post-survey, attitudes toward being comfortable with computerized lectures seemed to even out.

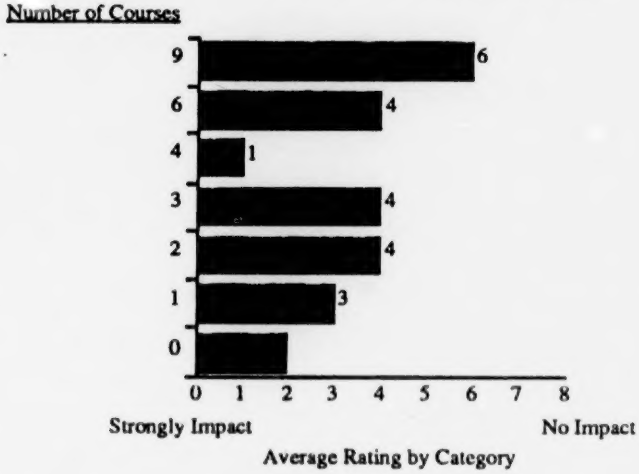

Figure 6. *Comfort by Computer Courses completed: pre survey*

Animations and attitude

Many of the lectures included animations of tables and graphs to visually represent concepts and ideas. The professor could, for example, when discussing interest rates, ask students to suggest an appropriate rate of interest. The given rate could be input into the computer and by animating the graph or table effects on other variables could be instantly represented. Students perceived the animation of concepts positively both prior to their exposure to animation and after long-term exposure to it. From the data collected students anticipated at the beginning of the semester that animations of graphs would be attention getting and useful (see figure 7). This perception remained constant, for the most part, from the beginning of the semester to the end.

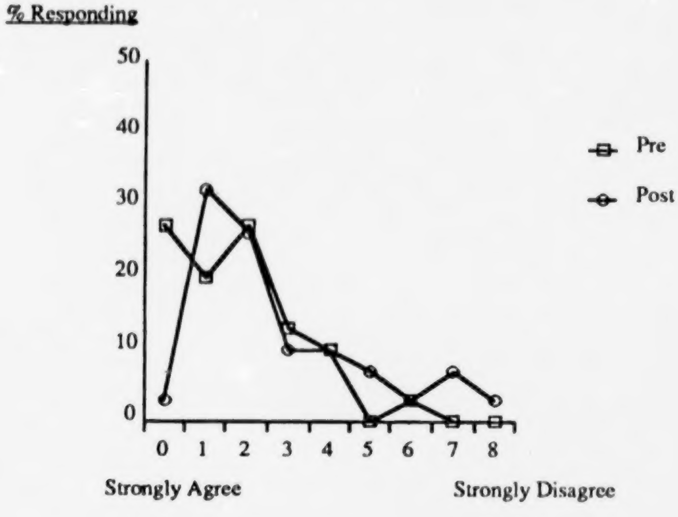

Figure 7. *Animating Graphs: pre and post survey*

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Summary

This pilot study attempted to make an initial assessment of student reactions to computer-assisted lectures and thus no efforts was made to control for extraneous factors which may have influenced student attitudes during the course of the semester. Given the constraints of this study, the researchers hesitate to make any generalizable conclusions, however, some interesting observations were made. First, video recording class lectures with two video cameras is an effective technique to assess the implementation of a new classroom technology. Video preserves rich details about observations which can be studied repeatedly and validated by other researchers (Van Dalen, 1979). One drawback to this technique is that video recording lends itself to the collection of large amounts of data and consequently requires substantial resources in time, money and energy to make thorough analyses. Second, upon review of the video recordings it appeared that students tended not to look at visuals which included text or formulas and appeared more attentive to animated tables and graphs. This was expected because students had the professor's typed notes with which to follow the lectures. Third, the subject population had very little computer knowledge or exposure to computer-assisted lectures. Results, however, from the pre-survey show that students anticipated that the lectures would be easy to follow and informative and that they would feel comfortable being taught with this delivery format. The researchers were concerned that students, without much computer familiarity, might be skeptical about the delivery format which may impact learning. Fourth, students appeared to perceive animation of concepts and ideas as useful and attention gaining. Moreover, its use in this study whereby the professor maintained an interactive dialogue with students and fed their responses into the computer and animated results, from the researchers' perspective, added additional dynamics to class lectures and assignments. This technique also helped to monitor student attentiveness in a large lecture room.

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MOVING COMPUTER GRAPHICS TOWARD MOTIVATIONAL DESIGN

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Abstract: Computer graphics are often claimed to provide substantial motivation impact on learning computer-assisted instruction. While considerable development effort has focused on designing computer graphics, more attention needs to be placed on motivational variables that contribute to the effective interaction between the graphics and the learners in order to deliver the important information in the instruction. An integration of Keller's ARCS model of motivational design (1991) is used in this paper to address the issues of attention directing, relevance matching, comprehension guiding , and satisfaction from the graphics in order to enhance the motivational elements of instruction. Specific guidelines are proposed based on the literature.

Introduction

Computer graphics have been widely used in today's computer-assisted instruction (CAI) and interactive learning materials as a strategy to motivate learning and to deliver important messages. With the advent of modern technology, various computer generated graphics software programs have been developed to enable graphic artists to design quality graphics (Alesandrini, 1987). New technology provides opportunities to make the designed messages more appealing to viewers. However, more attention needs to be paid to design issues, such as whether the graphics used are appropriate to target learners or whether the graphics used are relevant to the context to be presented.

It is easy to dazzle learners with attractive graphics in the computer or interactive learning environment without having much impact on what or how well things are learned (Dam, 1992). Graphics themselves will not provide any knowledge acquisition unless people who employ them provide appropriate links to the learning context. Written for instructional designers, this paper discusses design issues for graphics based on the motivational conceptual framework of Keller (1991). Incorporating findings and implications from the literature on graphic use, design variables are carefully considered. In addition to focusing on the visual aspects of graphics, this paper also emphasizes the motivational factors related to effective interaction between perceptions of graphics and learner characteristics.

Motivation Factors

Motivating learning is an important issue that has been too little explored in research and theory (Reigeluth, 1993). Researchers have recognized that different motivations influence achievement (Mizelle, Hart, & Carr, 1993). However, how instruction should be designed in order to encourage students' involvement in learning requires further exploration. "More work is needed in this area, especially regarding motivational strategies which are uniquely possible with advanced technologies" (Reigeluth, 1993, pp. 53).

According to Keller (1987, 1990), the motivational quality of instructional materials is affected by considering the major strategies for attention, relevance, confidence, and satisfaction. For enhancing the motivational aspects of graphics in a CBI lesson, it is essential to understand how each individual varies in processing graphics and how graphics can be provided through the instructional materials in order to support perception, understanding, and memorization (Cate, 1993; West, 1992). Since there exist differences among individuals in organizing, transforming, evaluating, processing, and encoding ability (Paivio, 1990), it is essential to take into account learner characteristics, such as their gender, age, cognitive ability, and their knowledge background is order to meet the purpose of the designed graphics.

Applied in graphics design, Keller's ARCS model is used to identify ways that graphics can be provided to fulfill motivational requirements. The model is a problem solving model and also a model used by instructional designers or instructors to analyze motivational requirements (Visser, 1990). In this paper, the ARCS model is used as a motivational framework to derive strategies for designing computer graphics (Table 1). In the following sections, how these motivational strategies can be extracted and applied in designing computer graphics is discussed in detail. These strategies prescribe the requirements for graphics design with an aim to provide a motivational learning environment in computer-based materials.

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Attention

Since computer-assisted instructional materials are usually employed for self-paced learning, getting and sustaining learners' attention is an essential prerequisite to involvement in the learning task (Keller & Burkman, 1993; Keller & Suzuki, 1988). The use of graphics in instruction, especially in computer-assisted instruction, is an instructional strategy that merits attention (Alesandrini, 1987); affective and emotional reactions are more easily to be activated with images than words (see review by Paivio, 1990). The capability of graphics for attaining and sustaining attention is derived from the psychological effect they provide for perception arousal. The stages involved in perceiving information involves receiving any given information as stimuli through sensors and cognitively selecting and filtering the elements among given stimuli. Attention of learners needs to be guided since the perception of an image varies depending on their previous experience, mood, and personal interests (Pettersson, 1989).

Used without precaution, graphics might harm learning. Presumably, the use of computer graphics in CAI materials is to motivate learning by guiding learners to important messages. However, irrelevant graphics contribute little in motivation or might even distract learners from acquiring important information (Alesandrini, 1985). Lack of potential links between personal interest and context presented might make the graphic materials confusing to the intended learners. It's worth further examination about how to effectively employ graphics to facilitate learners' perception arousal, interest matching and learning curiosity from the given information. Several strategies for attention getting are described in the following section.

Perception Arousal for Getting Attention

It is observed that motion creates potential learning interest during interaction with computer-assisted materials (ChanLin, 1993; Rieber, 1990). With the integration of new technology, such as animation and visual effects, graphics can more easily affect the perception of given stimuli and provide learning interest and promote incidental learning from the instructional materials (Alesandrini, 1987; Rieber, 1989a; Rieber, 1990). Due to the physical differences in the ways information is presented, the use of these design techniques offers potential visual contrast over the static background to catch viewer's eyes and emotion (Hannafin & Peck, 1988). Use of cueing devices, such as color, labels, and arrows can aid discrimination or facilitate the identification of essential learning characteristics in the visualized message (Beck, 1987). The instructional stimuli received by the senses must be adequately coded prior to being transmitted and processed (Lamberski & Dwyer, 1983). Since pictorial materials often contain large numbers of stimuli, the learners may need assistance in locating the most relevant information. If learners do not receive sufficient direction for coding the essential part of the information, learning will likely become less than optimum.

Inquiry Arousal for Getting Attention

When various design strategies are employed in gaining learners attention, instructional designers should move their focus from facilitating sensor-level reaction (perceptual curiosity) to information seeking or problem solving reaction (epistemic curiosity) (Keller, 1983). Understanding the environment surrounding the learners, and trying to integrate the events or objects that are relevant to their learning interest is more likely to encourage learners' involvement and their curiosity in information seeking. Matching design objects with contemporary events or learners' current interests creates substantial curiosity when searching specific information (Alesandrini, 1985). To attract and maintain curiosity, the learning materials should not only give people the opportunity to learn more about things they already know about or believe in, but also give them moderate doses of the unfamiliar and unexpected (Keller & Burkman, 1993). The selection of graphic objects requires designers' creativity in creating an interesting learning environment. The inclusion of unusual and exotic materials can help viewers initiate or maintain curiosity.

Variability for Getting Attention

The use of various graphics is a way to prevent learners from feeling bored, and at the same time, to provide opportunity for learners to visualize different interesting themes for interaction (Hannifin & Peck, 1988; O'Connell, 1992). A novelty approach encourages learner's curiosity in exploring interests (Keller, 1983; Keller & Burkman, 1993). With inclusion of diverse visualization, learners are invited to continue seeing novel themes in the program. The use of different attention getting treatments in the graphics also encourages learner's curiosity in exploring new interests and in gaining new insights from the learning materials (Dam, 1992). It was observed that the aesthetics of graphical materials stimulate people's emotional feelings that can command attention (Horton, 1991; O'Connell, 1992). The use of multi-dimensional representations of a graphic also allows effective attention to the information because it encourages a viewer to explore and to construct an understanding in a more meaningful way (Haertel, 1992).

Relevance

Designing graphics for effective communication needs to account for how learners make predictions and evaluations from the information perceived (Reynolds & Baker, 1987). Prior to designing graphics, it is important to consider what might impel people to learn, and determine what might stimulate people's desire in learning from the materials provided, and then design the materials to meet those motivational purposes. The important implications of successfully employing graphics in facilitating interest, comprehension and retention of the messages is not only grounded upon whether those pictures contribute to reflecting the textual messages but also how well the message is designed to be perceived, understood, and remembered by the learners in the way expected (Schallert, 1980).

The meaning of pictures is not inherent but is the result of constructive processes that a learner brings to bear on the message (Schallert, 1980). Learners exhibit strong tendencies to interpret and remember visualization in terms of their existing knowledge. Based on the interaction between the pictorial message and students' understanding about the area they are studying, they translate the pictorial message with their own meaning , and then reconstruct their existing knowledge by integrating the translated meaning from the message. Under this implication, selecting graphics to reflect the messages that guide a learner's interpretive and constructive process from what they already know and what they are familiar with is important. Strategies for increasing the relevance of the lesson for the learners, such as goal orientation, motive matching and relating familiarity are discussed in the following section.

Goal Orientation for Providing Relevance

Goal orientation is considered by Keller as a value judgement for learners to link the new learning with their perception of importance (Keller, 1983). Learners make their own decisions about whether the knowledge is important for them to obtain. Designing graphics for effective communication needs to account for how learners make predictions and evaluations from the information perceived (Reynolds & Baker, 1987). The graphics selected should be relevant to the message provided in the sense that they help visualize what needs to be learned. Additional cues or excessively realistic cues might become distractions to learners, because irrelevant cues evoke competitive responses in opposition to desired learning. Although the effects of different levels of pictorial realism vary depending upon the levels of students prior knowledge, the pacing of the instruction, and the type of educational objectives to be achieved (Joseph & Dwyer, 1984), it is important to present the design with a format that allows learners to capture the central concept of the message.

Motive Matching for Providing Relevance

To use graphics for relating learner's interests and understanding viewer's cultures and characteristics is important (Horton, 1991). Since graphics affect certain emotions, making predictions about what viewers perceive from graphics is essential to using the graphics for achieving specific emotional purposes (Cate, 1993; Kovach, 1988). The selection of graphic objects requires an understanding of the characteristics of the learners, their environment, and their current interest. It also requires creativity to link the instruction with the realistic world. Research has shown that people's responses obtained from pictures affect how information is perceived, stored, and retrieved (Langhinrichsen & Tucker, 1990; Lehmann & Koukkou, 1990). Relating graphics with things that interest viewers is expected to create memorable impressions and substantially enhance involvement in learning (O'Connell, 1992). However, this approach should be employed with precaution. Since there exist differences in gender, culture, language, or learning style among viewers, the effects, actions, or thoughts evoked by a graphic might vary among different groups of learners (ChanLin, 1993). Specific graphics that encourage the potential learning motive of one group might not have the same impact on another. Consideration of individuals needs to be taken when doing graphics design. One should carefully examine whether a specific culture or sex group is excluded from the design if the instruction is used to reach a larger group of viewers (Horton, 1991).

Familiarity for Providing Relevance

Tying new learning to what is familiar to learners can facilitate the comprehension and memory of new concepts since learning involves reconstruction and integration of new information with existing knowledge (Gagnè, Briggs, & Wager, 1992). In computer lessons, graphics are used as cues to trigger the ideas from relating concepts and prior experience associated within the learning context. Since graphics are used as a cue to help encode important information (Beck, 1987), they should be meaningful to the intended viewers (Cate, 1993). If the graphic image is familiar and meaningful to learners, it promotes intuitive responding and facilitates encoding during the process of learning (Begg, 1983; Mealing & Yazdani, 1990).

Abstractness and unfamiliarity are two factors that tend to reduce curiosity and learning (Keller, 1983; Keller & Burkman, 1993). A graphical representation should take advantage of this principle by exploiting analogies

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between an already know domain and a to-be-learned one. Analogy and metaphor can help learners relate new, unfamiliar, abstract knowledge to something that is concrete and familiar, and thereby capture its essence (Alesandrini, 1987; Cate, 1993). Computer graphics are often employed as a visual language to quickly communicate with certain groups of people who share a specific culture. If graphics are to be adopted by learners as a comprehension tool, they should be a visual representation that is easily grasped for referencing the information (Cate, 1993; Richardson, 1990). Effective use of metaphors and analogies is dependent on fully understanding the knowledge and the visual world from the point of view of intended learners (Cate, 1993).

Confidence

People's attitude toward success or failure has great influence on their learning performance. The important implications for providing motivation in the instruction is to make the learning materials assist a positive expectation for success and enhance the student's beliefs in their competence (Alesandrini, 1985; Keller & Burkman, 1993). To increase confidence in success, instruction should be embedded with necessary elements to make students believe that the instructional materials are the tool to expected achievement. Therefore they will devote their effort in perusing the materials given. To encourage students to use pictures to decode or cue the important information for which the graphics are designed, carefully studying how students interact with those graphics, and designing graphics to fulfill students' learning requirements is essential.

Learning Requirement for Providing Confidence

Presenting learning requirements is critical to helping learners build a positive expectation for success (Keller, 1983). Integrated into instruction, graphics can be employed as a primary source of information, an analogy to explain concepts, or a cue for focusing important information (Fleming, 1987; Hannafin & Peck, 1988). In order to fulfill the learning requirement and make graphics clear in the context represented, they should be consistent and correspond to textual messages, and presented simultaneously with corresponding text, so that students can inspect the graphics and the explanation together (Hannafin & Peck, 1988). In many cases, a single picture might contain important information to present a sequence of related concepts that are necessary for achieving intended instructional outcomes. Presenting a complex graphic should take into consideration differences in student's levels, abilities, and the types of instructional objectives that are to be accomplished. If a picture is too complex for consuming at one time, it should be dissected into smaller pieces (Fleming, 1987). If a picture contains too much information to present concepts, adding the details or complexity gradually is needed (Fleming, 1987).

Positive Consequence for Providing Confidence

Positive consequence is important in enhancing students' beliefs in their competence with the learning experience provided. A learning task that is too simple or too difficult might not encourage students to engage in the task provided (Keller, 1991; Malone, 1981). Graphics should be appropriate to task difficulty (Dwyer, 1988). Graphics containing too little information may not be adequate to challenge students and may cause them to become uninterested; graphics containing too much information may tend to overwhelm students and cause withdrawals from necessary interactions with the graphics which will enhance the learning experience. An appropriate level of learning difficulty is desired (Alesandrini, 1985). To maintain learners' intrinsic interests and quantity of performance, motivating feedback is suggested following responses. Although a lesson is more motivating when it challenges learners by providing graphical feedback on progress toward the learning goal, the use of graphics is not equally emphasized in all kinds of responses. The graphics should always reinforce and enhance positive learning rather than reward mistakes and failure (Alesandrini, 1985; Hannifin & Peck, 1988).

Personal Control for Providing Confidence

To encourage students to exert effort, the learning environment should provide the opportunity to allow students to accessing the important learning information at their own pace and at any time they want to (Alesandrini, 1985). Different individuals have different ability in learning from graphical materials. When learning under self paced conditions, sufficient learning time is essential for students to take full advantage of the information provided in the graphics.

Students' confidence about learning specific content is also influenced by whether they feel they can easily navigate through computer learning materials and access information they need (Litchfield, 1993). Cognitive maps or other visual organizers are effective tools to help organize thoughts and clarify directions and lesson flow. They also provide substantial improvement in help retention. These cognitive maps not only help students to represent abstract or implicit information in more concrete form, depict the relationships among facts and concepts, but also help generate and elaborate ideas (McTighe & Lyman, 1991). Students gains substantial control over the materials when they know what they are learning about and how they can proceed through the learning with the organization provided.

Satisfaction

Satisfaction toward learning is an emotional state evoked when engaging in instruction (Keller, 1991). It can be addressed from two aspects: enjoyment from the learning process and personal satisfaction from accomplishment. The former refers to the stimulating or exciting experience during the process of learning, while the later refers to the feeling of succeeding at a task. To provide students with an enjoyable learning experience, graphics should be well produced so that students view learning as an interesting task (Levie, 1987; Wileman, 1993). Since computer assisted instruction is often employed as self-paced instruction, keeping a substantial level of involvement with the materials is essential. Students' feelings of achievement are determined by the result of their effort with given tasks (Keller & Burkman, 1993). To facilitate learning concepts from graphics, instruction should provide opportunities for students to practice the material with questioning during instruction (Rieber, 1989b; Rieber, Boyce & Assad, 1990; Rieber & Hannafin, 1988). Practicing is even more important when a new concept is introduced or when potential mental effort for rehearsing is required to establish familiarity. If the instructional environment does not provide the opportunity for learners to practice or rehearse the graphic materials, the instruction might fail in helping learners gain a feeling of accomplishment from the learning task.

Intrinsic Reinforcement for Providing Satisfaction

Maintaining a substantial level of intrinsic motivation is important for encouraging achievement in learning (Brophy, 1986; Malone, 1981). With intrinsic reinforcement, students are willing to invest their effort by their own choice (Keller, 1983). The use of well produced graphics aims to provide students with an enjoyable learning environment so that they view learning as an interesting task and continue to experience enjoyment. Graphics should perform as a facilitator for encouraging thinking, identifying, experimenting, and transforming the skills in the learning environment (O'Connell, 1992). A creative combination of varying interactive tools, such as animation or interactive themes, that allow learners to explore is desired. Well-produced graphics are the keys to stimulating, satisfying learning experiences and the acquisition of specific knowledge (Eisner, 1985; Levie, 1987). Especially in the science area, good quality graphics are essential to the understanding of information. By providing good quality graphics, students can learn better because they are encouraged to discover and gain insights into interrelationships among concepts through interacting, thinking, and experimenting in a more realistic situation (Brown, 1992).

Extrinsic Reinforcement for Providing Satisfaction

Providing potential rewards can encourage students to exert effort toward a task that might or might not be interesting to them (Keller, 1983). Through the incentives presented from instruction, students are encouraged to engage in learning tasks (Brophy, 1986). It is observed that when the learning tasks are less interesting and require more mental effort, more interesting graphics are needed for providing incentives (ChanLin, 1993). Since the reinforcements from graphics is to provide the connection between learning enjoyment and intended learning performance, various creative strategies (such as humor or exaggeration) should be employed especially when the learning tasks are less interesting or require more processing effort (ChanLin, 1993; Fleming, 1987; Peeck, 1987). When students obtain sufficient level of familiarity with the graphics provided, inviting them to visualize the knowledge they construct is essential. The major purpose of using visualization is an aid to help students develop their own visual representation about the concept (Schallert, 1980). The opportunity to explore and experience the representations through the instructional setting promotes the reconstruction in students' minds of the essential elements that need to be emphasized in the real situation (Friedman, 1993).

Equity for Providing Satisfaction

To satisfy learning curiosity is to provide learners with certainty that their achievement in the instructional setting is the same as what they have to experience in the real environment (Keller, 1991). Graphics provide paths of understanding to achieve intended instructional purposes. Ways of relating graphics with the tasks that need to be performed in a real situation are desired (Brown, 1992). Especially in learning science concepts and problem solving skills, the opportunities for students to visualize and relate to a realistic pictures are essential (Dwyer, 1988). The use of this strategy is not only to reinforce what is presented, but also to help confirm what is learned and accomplished in order to establish their belief of success in the future.

To promote knowledge acquisition, students should be provided with opportunity to relate their newly acquired knowledge with real objects or real applications they need to perform. It is observed that a simulation approach allows students to act in a meaningful way. Assimilation of new knowledge from the realistic experience promotes long term memorization (Dwyer, 1988). There is a growing consensus among cognitive sciences that to perform successfully in a particular task domain, one must have sufficient real-life experience (Greeno, 1989). The role of graphics in instruction is to provide a link between domain knowledge and the representation within

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students' minds (Friedman, 1993). Through experiencing and constructing, students are able to mentally visualize the objects and to form their knowledge framework (Morris & Hampson, 1983; Shepard, 1975). With the framework formed internally, they can use it as a basis for making inferences in future knowledge acquisition and real life performance.

Summary

To accomplish motivational requirements, designed graphics should focus both on appeal in the sense of pleasing the eye and provision of the elements required to meet the learning tasks. Prior to development, identifying what the instructional purposes are and how the motivational strategies can be used in facilitating different motivational purposes is essential.

Although recent literature (e.g., Brown, 1992; O'Connell, 1992) has addressed the merits that computer graphics provide in enhancing interaction and exploration, these merits are supported only when the motivational requirements are met. Motivation in learning computer or instructional materials, for learners, is the initial indicator influencing a learning process in a given task (Keller, 1988; Keller & Burkman, 1993; Litchfield, 1993). How students approach, interact, and perceive computer or interactive learning materials is directly related to how they perceive the task and the situation given (Litchfield, 1993).

Although in computer graphics design, a focus on the four motivational issues (attention, relevance, confidence, and satisfaction) has not been emphasized in the literature, designing graphics to fulfill the requirements in gaining and maintaining students' attention, relating to their interests, building up their confidence in understanding, and satisfying their learning curiosity is an important factor in encouraging involvement in learning from computer-based materials. From a motivational aspect, to be interactive and motivating, computer graphics should be able to mimic the real world interaction, and encourage learners to think and to capture their imagination, and to help them move through their own creative ideas more easily. It becomes a challenging task for a graphics artist to generate graphics that are capable of facilitating learning motivation (Wileman, 1993).

Although graphic design requires proficient skills in the use of available software packages, to make graphics motivational, employing motivational design strategies is expected to move computer graphics toward a more effective approach. Carefully examining the motivation purpose of graphics used in relation to the instructional context provided, and the levels of learners in interpreting the graphic materials, is a critical process prior to the production of materials. Through the motivation framework provided, graphic designers are invited to view the designing task from a boarder perspective. With this approach, the different motivational factors among attention, relevance, confidence, and satisfaction are focused upon.

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Table 1
Motivation Strategies for Graphic Design

ARCS Model, Keller (1991)	Strategies for Graphics Design
Attention	What can be done in graphics to help attention getting and maintaining?
Perception Arousal What can I do to capture students' interest in the computer learning materials?	• Use graphics that are eye-catching to initiate learning interest (Rieber, 1989a). • Use visualization that is concrete rather than abstract to facilitate attending the concept (Dwyer, 1987). • Cue important elements in graphics to lead attention (Beck, 1987)
Inquiry Arousal How can I stimulate an attitude of inquiry?	• Match graphic objects with learner's current interests (Alesandrini, 1985). • Use graphic objects that stimulate curiosity (Alesandrini, 1985).
Variability How can I maintain their attention?	• Vary graphics to provide for different interests (O'Connell, 1992). • Employ various graphic formats and styles for sustaining attention (Haertel, 1992).
Relevance	What can be done in graphics to establish students' perceived relevance in learning from the instruction?
Goal Orientation How can I relate the instruction to the learner's goals?	• Use graphics relevant to the purpose that the instruction intends to achieve (Reynold & Baker, 1987).
Motive Matching How and when can I link my instruction to the learning styles and personal interests of the learners?	• Match design objects with contemporary events or learner's current interest (Alesandrini, 1985). • Relate design with students' characteristics (Horton, 1991). • Make graphics individualized but not exclude specific group of learners (Horton, 1991).
Familiarity How can I tie the instruction to the learner's experiences?	• Use meaningful representation to convey information (Begg, 1983). • Use analogy and metaphor to convey unfamiliar and abstract concepts (Cate, 1993).

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Confidence	What can be done in graphics to establish students' confidence in learning the computer program?
Learning Requirements How can I assist in building a positive expectation for success?	• Correspond graphics with text (Hannafin & Peck, 1988). • Dissect complex graphics into digestible pieces (Fleming, 1987).
Positive Consequences How will the learning experience support or enhance the students' beliefs in their competence?	• Allow appropriate challenge level and full interaction with graphics (Alesandrini, 1985). • Use graphics to reinforce positive responses rather than negative responses (Hannafin & Peck, 1988).
Personal Control How will the learners clearly know their success is based on their effort and abilities?	• Provide a sense of control and choices for accessing graphical information (Alesandrini, 1985). • Provide a tool for organizing information through graphics (McTighe & Lyman, 1991).
Satisfaction	What should graphics do to establish satisfaction during the time of learning through graphics?
Intrinsic Reinforcement How can I encourage and support their intrinsic enjoyment of the learning experience?	• Use graphics to encourage exploratory thinking and transforming skills (O'Connell, 1992). • Use well produced graphics for intrinsic reinforcement (Levie, 1987).
Extrinsic Rewards What will provide rewarding consequences to the learners' success?	• Provide more interesting graphics when the tasks require more processing effort (Peeck, 1987). • Provide opportunity for practicing and experiencing success from graphics (Fitzgerald, 1989).
Equity How can I build learner perceptions of fair treatment?	• Help visualize the real environment through graphics (Brown, 1992). • Encourage students to apply and relate what they study from the graphics to real world situations (Dwyer, 1988).

* The subcategory used here is from the older version of ARCS Model, because "personal control" is more related to the graphics strategy described.

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The Effects of Metaphor and Analogy on Novice Learners in a Computer-Assisted Lesson

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Abstract: The main goal of schools is to help students learn. In a modern society rich in information, knowledge and skills, this requires schools to provide learners with the knowledge and skills necessary for full participation in the dynamic changes of societal evolution. However, while students spend almost one-third of their awake-hours in school, how much actual learning can be applied to their interactions outside of school? Not understanding new learning material or one's inability to transfer that learning to other domains has not only educational costs but also personal costs. The educational institution loses time and money through lack of adequate student preparation and the subsequent need for re-teaching. Individuals may develop learned helplessness and fear of school through constant exposure to "unintelligible" teaching and from the rapidly advancing norms of society.

The purpose of this study was to assess the effectiveness of techniques that enable students to transfer learning across knowledge domains, analogical reasoning. Analogical reasoning as a proposed intervention appears to be conceptually consistent with recent ideas and developments in cognitive learning.

An important concept relative to helping students understand new learning is by relating it to prior knowledge. However, not every student possesses prior school learning to relate new skill or knowledge elements to. To overcome this obstacle, analogical reasoning techniques can provide bridges to other analogous prior knowledge outside of the content area (Curtis & Reigluth, 1984).

Review of Literature

Prior Knowledge

From the perspective of cognitive psychologists, learning is a process of relating new information to previously learned information. It is similar to Piaget's assertion that accommodation almost always involves assimilation (Piaget, 1970). Information processing theorists believe that "learning is most likely to occur when individuals can relate a new experience to the information they have acquired from earlier experiences" (Omrod, 1990). Ausubel (1960) proposed that learning supported by prior knowledge can serve as an advance organizer.

Craik and Lockhart (1972) proposed that what gets encoded into memory depends upon the level or depth of processing of the presented information as it is perceived and encoded into memory during the learning process. As the level of processing deepens, then more information will be recalled because more meaning will be assigned to it (Ormrod, 1990).

However, people cannot always perfectly retrieve encoded information and this is "attributed to deficient retrieval strategies rather than simply forgetting" (Ormrod, 1990). If prior knowledge can be provided, learners will not have retrieval strategy problems.

presented before "Presenting stimuli with distinctive features" (Gagne, Wagner & Rohas, 1981, p. 182). All of these assertions support that accessing prior knowledge before instruction is very effective for learning.

Analogical Reasoning

Analogical reasoning is to relate what is to be learned to something with which the learner is already familiar (Gentner, 1983). This relation compares the new idea to an highly similar one that is known (Ortony, 1979). Analogical reasoning can be distinguished in two ways. The first one is classical analogies which involve four elemental comparisons in two main parts:

bird : feathers -> dog : hair

The second one is problem analogies that involve only two elemental comparisons in two main parts as exhibited in a learner recognizing the relational similarity between the solar system and the Bohr atom model. Goswami (1991) further identifies Piaget's structural theory and Sternberg's information processing theory as classical analogies and Gentner's structure mapping theory as problem analogies.

The effective aspect of analogies also depend upon the learner understanding a set of base knowledge (Gentner & Gentner, 1983) and noticeable relational commonalities between base and target domains (Getener, 1988, 1989). (Gentner & Gentner, 1983). Gentner also argues that the key to successful use of analogies is to notice relational commonalities between target and base domain, for example in the orbital nature of planets in the solar system and of electrons in a Bohr atom.

Novice and Expert

The difference between experts and novices in identifying problems is that "experts have a more complete and better organized knowledge base for the problems they solve (Cochran, 1988; Ormrod, 1990). Experts not only do know better which concepts should be associated with which, they also know the particular relationships that different concepts have with one another. Novices are often uncertain about how the different knowledges fit together and are more often wrong about how the concepts are actually interrelated, focussing on superficial physical characteristics rather than on functional characteristics.

Statement of the Problem

Using analogies to understand a new domain is widely accepted as playing a role in learning behavior. The application domains of analogies have been a diverse as science education (Gentner, 1977; 1983) and reading (Goswami, 1986). Clement et al. studied the consequence of analogical reasoning in the learning of programming languages (Clement, Kurland, Mawby & Pea, 1986). However, little attention has been focussed recently on the use of analogies to assist novices in learning computer languages.

Due to the novice level of the subjects in this research, no explicitly parallel schema can be assumed to exist in their knowledge base. Therefore, a teaching strategy using analogical reasoning was modeled according to an environment the students were likely to have experienced elsewhere. To that end, the process of cooking involved in the preparation, cooking and presentation of a meal is assumed to be common enough to be considered base knowledge for all participants. This cooking analogy is accessed in the lesson presented in this research.

The Research Project

This research was designed to inspect the effectiveness of analogies in improving the

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relative to BASIC computer programming concepts via computer-assisted-instruction (CAI) for both male and female learners.

Subjects

Novice learners in this study are defined as persons who have little or no previous experience with computers and lack specific knowledge of computer programming (Mayer, 1981).

24 students from an undergraduate Instructional Technology course, EDIT 2318, "Computers and Technology" at Texas Tech University volunteered to participate in this CAI lesson in return for "extra credit" grading.

Materials and Equipment and Facilities

Due to its inherent graphic capabilities, the ease with which a developer may incorporate interactive "stacks" (programs), and one of the researcher's experience with its development language, Claris "HyperCard™" for Apple Macintosh® computers was chosen as the media for delivery of the lesson. Lesson content and performance objectives were assessed and verified by content area experts; Dr. Bob Price, PhD., Mr. Roger Von Holzen and Mr. Donald J. Winiecki of Texas Tech University.

The site chosen for delivery of the lesson was the Educational Computing Center (ECC) lab, rooms AD325 & AD326 on the Texas Tech University Campus. Students enrolled in the EDIT 2318 course are required to use this laboratory for many of their class assignments and are familiar with its location and environment.

A total of five Apple Macintosh computers (four model SE and one model SE/30) were available for use during the lessons. Each of these computers is comparable in screen resolution, processing speed and operating characteristics relative to the needs of the presented CAI lesson.

Lesson times accommodated student and teacher schedules and varied from 8:00am to 4:00pm on a Thursday through Tuesday schedule.

The ECC lab was open for normal student use during some of the lesson sessions and activity during the lesson sessions ranged from low to very busy with a corresponding range of noise and potential distractions. Any effects resulting from these environmental changes is unknown. Although during lesson observations, some subjects appeared to be distracted by various activities in the room.

Instrument

A researcher-made test of 20 multiple-choice questions was developed. The purpose of this achievement test was to measure subjects understanding and mastery of BASIC programming concepts presented in the CAI lesson. Face validity of this test was was assessed and verified by content area experts; Dr. Bob Price, PhD., Mr. Roger Von Holzen and Mr. Donald J. Winiecki of Texas Tech University.

Post research analysis using the KR-20 instrument indicated an inter-item consistency of .71 among the study's 24 participants.

Procedure

Two weeks before taking the CAI lesson, the subjects' regular instructor explained to them the nature of the research project and administered a consent form for them to sign. In addition to the consent form, each potential participant completed a pre-intervention questionnaire (appendix A) containing three subtests; a Computer Attitude Rating Scale, Computer Anxiety Rating Scale and a Self-Efficacy Scale for computer use. Students participating in this research were awarded "extra credit" for their cooperation.

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Subjects were randomly assigned to one of two treatment groups:

Experimental Group

The experimental group received a CAI lesson presenting primary BASIC programming concepts with consistent use of analogies, metaphor with the analogies and metaphor embedded in the instruction.

Control Group

The control group received a CAI lesson presenting the identical primary BASIC programming concepts using onscreen text only. The control group was not exposed to any use of analogies or metaphors in the presentation of the CAI lesson.

Immediately following the intervention each subject was asked to complete a posttest and a post-questionnaire (identical to the pre-intervention instrument).

Two weeks following the intervention, subjects returned to complete a delayed test (identical to the post-test) to measure student's retention.

Results

Mean scores on the immediate post-intervention test were: control=76.15, experimental=74.09. Mean scores on the delayed test were: control=70.49, experimental=71.07. Analysis of variance revealed that there was no statistical differences between groups at the .05 level. Results are reported in table 1.

The results show that the control group had the highest score in both immediate and delayed post-test.

Item analysis of the post-test revealed that its item difficulty ranged from 25.49% to 100% and point item biserial discrimination achieved values of +0.75 to +0.494.

Average attitude toward computers increased .29, anxiety decreased .38 and self efficacy increased .25 within the control group. The experimental group's attitude toward computers increased .5, anxiety decreased .56 and self-efficacy increased .61. Results are reported in table 2.

Inter-item reliability of the questionnaire is presented in table 3.

Analysis of Results

From an analysis of variance, we found that the mean of post-test, delayed test, post-test anxiety and post-test self efficacy did not undergo significant change. However, significance was realized in post-intervention attitude with a covariate of pre-intervention attitude (F=3.24, P-0.031).

Interpretation of Results

The effects of activating a well known analogy as a schema during CAI was investigated. Apparently, the experimental treatment was too weak to have an effect on dependent variables. In brief, the assumption of using analogies to increase the attitude and self-efficacy and to decrease the anxiety toward computers and computer programming was not supported between groups.

Conclusions

A basic premise of this study is that learning does not occur in a vacuum. Learners must have appropriate schema to understand incoming information. In other words, learning is to have successful retrieval of appropriate schema from the long-term memory to give meaning and structure to the new information accepted into working memory and encoded into long term memory (Norman, 1988).

However, for the novice who may have no appropriate knowledge base, relating new knowledge to highly similar knowledge that is external to the learning domain is of interest

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(Reigeluth, 1983). The subjects in this research generally had little background knowledge of computer programming languages. For that reason, some way was needed to make the schema more concrete and understandable for them. This was attempted using analogy and metaphor.

For the above reason, we chose to present a lesson on the systematic nature of computer programming through metaphors and analogies representing a process that our students were likely to have had previous experience with. The metaphor and analogies around which this lesson is constructed are created by posing the computer itself as a humanoid robot engaged in activities normally experienced during the preparation, cooking and presentation of a meal (preparation, input, output in the programming process, appendix B). We thought the representation of the computer as "a thing to direct orders to" (eg: a robot) and the use of cooking procedures to model the programming process would provide an environment within which anxiety may be reduced and instruction presented in a familiar and more easily encoded format. Additionally, we expected test performance to increase, attitude toward computers to increase, self-efficacy toward computers to increase and anxiety caused by computers to decrease.

Disadvantages of this study include:

1. This CAI program contains no practice session. subjects were not given the opportunity to act upon new information.
2. Although novices to computer programming, subjects had widely varying experiences with computers in general.
3. Subjects attitude toward the metaphor and analogy used in this lesson may have had some effect on results.
4. Subjects were not prompted to use any presented analogies during post-intervention tests.
5. The intervention was only administered once for a period of approximately 20 minutes. Additional sessions or longer duration may have some additional effects.

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Appendix A. Computer Anxiety, Attitude, and Self-Efficacy Survey:
Adapted from Harrison & Rainer (1992).

EDIT Password: __________

For the questions (1-12) below, please circle the initials (eg: SD, N, SA...) representing how strongly you agree or disagree with each statement.

Use the following scale to rate your responses:

SD = Strongly Disagree
D = Disagree
A = Agree
SA = Strongly Agree
N = No Opinion

1. Computers can eliminate a lot of tedious work for people. SD D N A SA
2. Computers make me uncomfortable because I don't understand them. SD D N A SA
3. Computers intimidate me because they seem so complex. SD D N A SA
4. Computers are difficult to understand and frustrating to work with. SD D N A SA
5. I do not think I would be able to learn a computer programming language. SD D N A SA
6. I dislike working with machines that are smarter than I am. SD D N A SA
7. The challenge of learning about computers is exciting. SD D N A SA
8. I am confident that I can learn computer skills. SD D N A SA
9. I feel confident working on a personal computer (microcomputer). SD D N A SA
10. I feel confident understanding the three stages of data processing (input, processing, output). SD D N A SA
11. I feel confident using the computer to organize information. SD D N A SA
12. I feel confident writing simple programs for the computer. SD D N A SA

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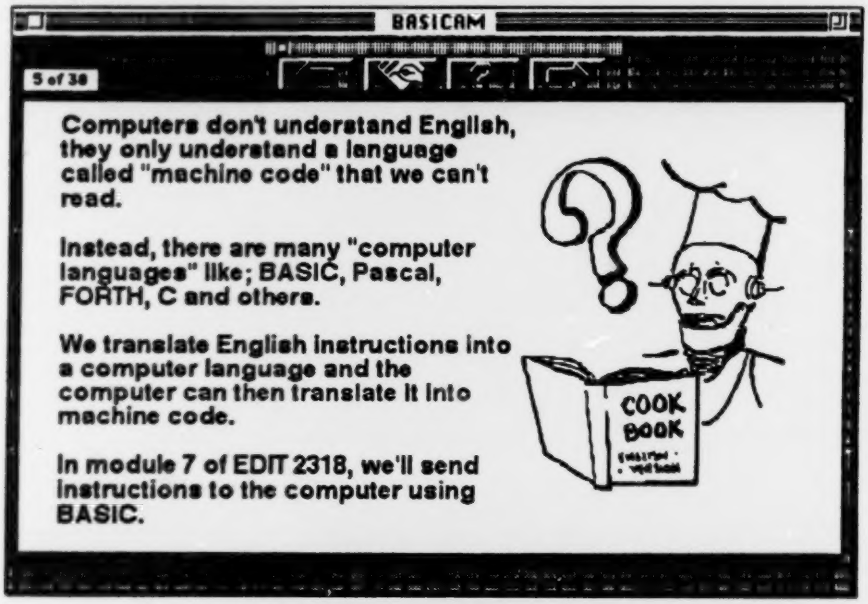
Appendix B. Hard copy output of CAI lesson screens.



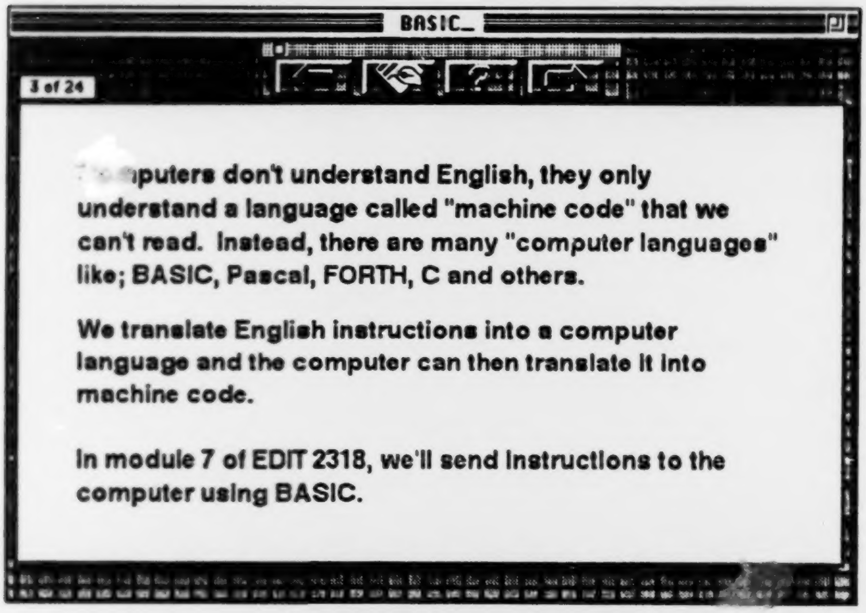
Computers don't understand English, they only understand a language called "machine code" that we can't read.

Instead, there are many "computer languages" like; BASIC, Pascal, FORTH, C and others.

We translate English instructions into a computer language and the computer can then translate it into machine code.

In module 7 of EDIT 2318, we'll send instructions to the computer using BASIC.

Typical Experimental Group Screen



[illegible]puters don't understand English, they only understand a language called "machine code" that we can't read. Instead, there are many "computer languages" like; BASIC, Pascal, FORTH, C and others.

We translate English instructions into a computer language and the computer can then translate it into machine code.

In module 7 of EDIT 2318, we'll send instructions to the computer using BASIC.

Typical Control Group Screen

Winiecki, D.J., Ahern, T.C. & Lin, S.L. (1994). The effects of metaphor and analogy on novice learners in a computer-assisted lesson. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 31-40). Nashville, Tennessee: Omni Press.

Table 1. Posttest and delayed posttest. (n = 24)

	n	Posttest Mean	Delay test Mean	Adj. Mean
Control	13	76.15	73.46	70.49
Experimental	11	74.09	72.27	71.07
F ratio		0.55	1.118	2.156
P value		0.65	0.352	0.107

Table 2. Questionnaire Survey. (n = 24)

		Pre-			Post			Differences	
	Att	Anx	Eff	Att	Anx	Eff	Att	Anx	Eff
Control	3.67	1.98	3.52	3.96	1.6	3.77	0.29	-0.38	0.25
Exp.	3.18	2.18	3.16	3.68	1.82	3.77	0.5	-0.36	0.61

Table 3. Inter-item Reliability (Alpha) on Questionnaire. (n = 24)

	Pre-	Post
Attitude	0.72	0.70
Anxiety	0.73	0.72
Self Efficac	0.78	0.74

Rieber, L.P. (1994). Using computer-based microworlds with children with pervasive developmental disorsers: an informal case study system. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 41-50). Nashville, Tennessee: Omni Press.

Using Computer-Based Microworlds with Children with Pervasive Developmental Disorders: An Informal Case Study

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Abstract: This paper presents an informal case study of an 11-year old child's interaction with several computer-based applications and microworlds. The child, diagnosed as having Pervasive Developmental Disorder resulting in multiple learning disabilities, has interacted extensively with a Macintosh computer since September, 1991. He has used several commercially available graphics packages as well as a series of specially designed software programs in the areas of language, mathematics, symbol manipulation, and general problem-solving. The child's case history is discussed both in general and in regard to his computer experiences. Examples of the instructional design and development of the customized computer microworlds, using rapid prototyping procedures, are also discussed.

This paper is about a child named Thomas. Thomas has significant developmental and behavioral disabilities that have presented him with unique challenges to learning, social interaction, and social acceptance. Consequently, he has great difficulty with the simplest of learning tasks. However, he is slowly finding an important ally in the computer. This paper tells the simple story of how Thomas and the computer have begun to work together as partners in cognition — a story that continues to evolve.

This paper is written from a special point of view because I am Thomas' father. For this reason it is written from my background in instructional technology, not special education. Likewise, there is no pretense in trying to present this story in any objective way. My work with Thomas stems from an admittedly selfish base. However, it is hoped that many will find some value and relevance in this story despite the inherent bias. At the very least, it is hoped that this paper may cause some to reflect more deeply on how to celebrate the diversity in all people.

Thomas' story will be told through the computer software he uses. Some of the software (i.e. *MacPaint, HyperCard, KidPix, The Playroom*) have been commercially produced, whereas I custom built other software for him. It would not be accurate to say, though, that *I* designed the software *for* Thomas. In reality, he should be considered as a "co-designer" because the most successful software I've developed for him have been based on his unique abilities and interests. Either the software reaches Thomas on his level or it simply does not reach him. As a result, Thomas has taught me a great deal about software design.

The purpose of this paper is to describe Thomas' progress and obstacles to understanding critical aspects of both general symbol manipulation and general computer operation. In Thomas' case, each has been wedded to the other.

Background

At the time this project began, Thomas was 9 years old. He had exhibited several severe learning disabilities from about the time he was one year old. In addition, he exhibits both severe developmental delays resulting from language disorders (e.g. form, content, and function uses of language) and speech disorders (e.g. articulation), though it would be misleading to suggest that the two areas are independent of each other. Most developmental psychologists agree that language processes play a central role in intellectual development, though the issue of whether language determines intelligence or visa versa is still widely debated.

Thomas has difficulty with even the simplest intellectual skills, such as making simple discriminations. His reading skills are limited to recognition of only several letters and a few sight words. His mathematical skills are confined to simple counting from 1 to about 5, though he does so apparently from rote. His construction of number theory usually seems limited to 0, 1, 2, and many. Thomas' writing ability is limited to crude representations of only a few letters and numbers. The only word he is able to write with accuracy is his nickname — "Tom." Thomas is

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severely deficient in some of the most fundamental cognitive abilities that we all take for granted — simple language, simple mathematics, and basic social skills. Therefore, his view of the world is likewise limited. His "knowledge" seems completely tied to specific situations and tasks with general transfer severely limited.

Thomas also exhibits behavioral disorders. He typically goes through periods of intense frustration and aggressive behavior for days at a time. Occasionally, he will experience a severe episode where he can no longer control himself and he will seem filled with rage. These are obviously very difficult periods for our family (we also have a 14-year old daughter). We are beginning to see a correlation between these extreme episodes and times of general stress in the family, such as very busy times, inconvenient travel schedules, and moving. In contrast, Thomas appears to most people as a very sweet child otherwise, though his responses and behaviors to simple social interactions often appear odd and confusing to people, especially strangers. He also has a very good sense of humor. Though it may be an oversimplification and too speculative at this point, we have noticed that Thomas' most disruptive behavior is often tied to times when he does not have control over a situation, whether due to an inability to comprehend what is going on or due to physical limitations (such as going on long car trips).

From a pure Piagetian perspective, Thomas' developmental level appears to be somewhere in the preoperational range. For example, Thomas is just beginning to develop temporal abilities that extend beyond to something happening the next morning or the next day. Thomas shows no sign of being able to conserve, though it is difficult to test Thomas because of his language comprehension disabilities. Thomas is almost entirely ego centered. He seems to view the world only in terms of how it affects him, a typical characteristic of this stage.

After receiving extensive clinical evaluations, he was diagnosed as having pervasive developmental disorder (PDD). In addition, he has been diagnosed as having attention deficit-hyperactivity disorder (ADHD). PDD is a general description given to individuals exhibiting a wide range of developmental disabilities (Brown & Reynolds, 1986) and is defined as children "in which many basic areas of psychological development are affected at the same time and to a severe degree" (American Psychiatric Association p. 34). This term is most often used to classify individuals whose learning disabilities do not easily fit other existing taxonomies, though PDD is usually grouped together with autism (but even on this point there is wide disagreement) (Bullock, 1992). People with PDD have learning problems that are related to a multiple of factors. The term PDD is used to describe a disorder that is simply not yet well understood. As is typical, a label often precedes understanding, but with it comes the risk that some will substitute the label for understanding.

Despite these extensive developmental and behavioral challenges, Thomas has many talents and aptitudes. He is musically inclined — he shows a good ear for melodies and lyrics and is particularly fond of musicals. He has memorized melodies and lyrics for entire songs (even though he has been unable to memorize individual letters of the alphabet in this way). He has very good visual skills. Drawing is one of his favorite pasttimes. He demonstrates a natural ability to coordinate colors (e.g. he chooses his clothes carefully with matching or complementary colors). He is also becoming very adept at operating a Macintosh computer, an ability on which the rest of this paper is based.

In September, 1991, various computer activities were introduced into Thomas's home school curriculum.[1] Thomas has been given on average approximately two hours of structured computer time each week in a university setting combined with casual access to a computer at home, resulting in approximately 10-15 hours of computer interaction per week on a continual basis. Thomas has extensively explored the graphics capabilities of several simple packages such as *MacPaint*, *KidPix*, and *HyperCard*. In addition, several computer-based activities were specifically designed to give Thomas simple and structured experiences in language and mathematics. These customized materials, designed and developed using rapid prototyping methods, have been in the areas of simple mathematics, letter recognition, shape recognition, general symbol manipulation (e.g. meaning of arrows), and left/right differentiation. Other goals of the materials were to improve Thomas's general cognitive skills (e.g. increasing his ability to selectively attend to components of a task), to establish a meaningful context for interacting with language and mathematics, to increase his self-esteem and self-efficacy, and to increase his ability to work independently. His use of the graphics applications and many of the customized software programs conforms to the use of computer microworlds as defined by the constructivist paradigm to learning (Rieber, 1992), though tempered with extensive use of game-like features (see Rieber, 1994a, for an extended discussion of blending the characteristics of microworlds, simulations, and games).

The computer is becoming an ever increasing ally in Thomas's intellectual repertoire. He has entered into what some call "cognitive partnerships" with the computer (Salomon, Perkins, & Globerson, 1991). His skills and abilities are closely aligned with the capabilities of the computer. Just as a normally functioning person still relies on the media of pencil and paper to supplement memory limitations, Thomas has begun to rely on the computer for many of his intellectual achievements.

The First Encounters

Thomas' first computer experience was with *Kids on Keys*, an older letter recognition package on an IBM-compatible computer that uses animation in a drill and practice format. The user must find and press the letter on the keyboard corresponding to an animated letter slowly "falling" on the computer screen. If the user is successful, the computer graphically "zaps" the letter. Thomas enjoyed the game despite a complex interface that frequently interrupted his play. For example, after correctly "zapping" a certain number of letters, the computer prompts the user to proceed to the next level. Early on, this always required adult intervention, although interestingly, Thomas quickly learned to imitate the key press procedure. Still, the package always required some adult intervention at some point. The package also did not contain any audio elements, so Thomas was learning only to discriminate on the letter shape, not the letter name. Given these limitations, I decided to custom design a similar package for Thomas.

The software I designed, called *Letter Match*, also had letter recognition objectives similar to *Kids on Keys*. However, the other intent also was to familiarize Thomas with software using a mouse interface, specifically the concept/procedure of "aim and click." This second goal turned out to be the real value of *Letter Match* because the primitive mouse skills that Thomas achieved with *Letter Match* became the building blocks for interacting with all of the other software described in the rest of the paper. Thomas is now very versatile with the mouse interface and uses the mouse as an "extension of self" like any other Macintosh or Windows user.

Letter Match begins with a digitized picture of myself followed by the audio message "Hi, Tom! Point and click on my picture to begin." The audio message is repeated after about 20 seconds. When successful, the audio message "Thank you!" is given and the software proceeds to the letter recognition task. All other input is ignored by the computer. The letter recognition task uses only the keyboard, just like *Kids on Keys*. After three successful letter matches, the software branches back to the mouse activity using my picture. At first, I had to help Thomas with the point and click task by guiding his hand and finger on the mouse. By the end of the first session, he was able to perform the task alone with only limited intervention.

The software then repeats this procedure until the someone quits the software using a pulldown menu option, a skill he has now completely mastered although it is not clear whether he has developed a rudimentary sight word vocabulary to include "Quit" or simply uses the spatial arrangement (i.e. last word on list) to make the correct choice. Fortunately, "Quit" was the only choice in the pulldown menu in Letter Mat*ch*.

Thomas still chooses *Letter Match* on a periodic basis, though I think it is just for the purpose of reliving an exciting discovery which became a starting point for his other computer adventures.

Learning to Recognize, Understand, and Manipulate Abstract Symbols

After a few sessions with *Letter Match*, I introduced Thomas to *MacPaint*, one of the simplest graphics packages on the Macintosh, with the hope that his graphical interest and ability would intrinsically motivate him to turn the computer into a graphical "construction set." His "aim and click" skills were sufficient to allow him to begin drawing. Early on, even though his fine motor skills with the mouse were quite poor, this did not seem to interfere. He seemed more interested in the "phenomena" of making lines and scrawls on the computer screen than drawing any recognizable picture. I also introduced him to *MacWrite*, a simple word processor, but he showed absolutely no interest with it. Even now, for whatever reason, when he is working on the computer he continues to avoid most uses of symbolic language, such as letters, words, and sentences.

For the first few months, his computer experiences were limited to *MacPaint* and *Letter Match*. He chose to split his time fairly evenly between the two. When working with *MacPaint*, Thomas relied on me to first choose the "large paint brush" tool from the program's tool palette. At first, he was completely unaware of any other function. Interestingly, he quickly identified the interesting and unexpected goal of filling up the entire screen as though he were painting a wall. When he achieved this for the first time, I changed the pen pattern from black to a light shade of gray. He proceeded to paint over the entire screen again using this new pen shade. The goal of painting the entire screen, with varying pen patterns and shapes, became his primary "mission" when working with *MacPaint*.

When working with *MacPaint*, he never showed any overt understanding of how a screen symbol, such as the "eraser," would change the function of the mouse. However, anytime I intervened to change tools for Thomas, I was always careful to describe what I was doing. For example, after filling up the screen, I would ask him if he wanted to erase it. If he said yes, I would say, "OK, I'll click on the eraser" while demonstrating it for him. He would then take over the mouse and begin erasing. Obviously, Thomas was very dependent on me in his use of *MacPaint* at this time. His standard routine was to draw with one tool and then ask for help to change to another tool.

Thomas' first real breakthrough occurred about six months later when he made the discovery of how to choose a different graphical tool for himself. It is easy to take for granted the conceptual leap that is necessary in understanding how one input device such as the mouse can assume multiple functions. This conceptual understanding is necessary for successful interaction with even the simplest software programs. While it might take a normally functioning 10 year old child only minutes to form this concept, it took Thomas six months.

This breakthrough began Thomas' adventures with the computer that closely conform to the constructivist idea of a microworld. He appropriated the technology to fit his needs and expectations while being engaged in authentic

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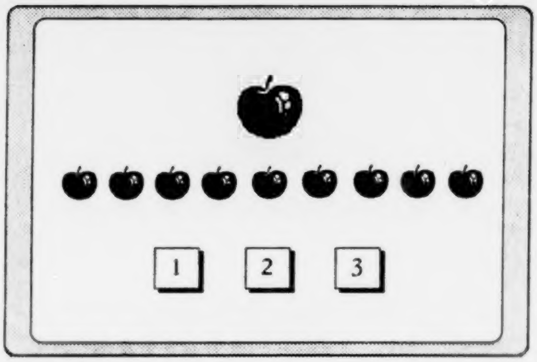

Figure 1. Snapshot of the screen at the start of *Sour Apple*.

experiences in a variety of contexts and domains, including mathematics, spatial manipulation, and language. *MacPaint* was replaced with the graphical environment of *HyperCard*, due to some technical problems I encountered with the latest Macintosh system software. Fortunately, the graphics of *HyperCard* are almost identical to *MacPaint*, though *HyperCard* uses different types of tool and pattern palettes. Interestingly, Thomas has learned how to access these palettes by "tearing them off" of the menu bar and the placing them just where he wants them.

Adventures with *KidPix*

Based on Thomas' success with MacPaint, I introduced him to a very creative and imaginative graphics package for children called *KidPix*. This, by far, is Thomas' most favorite computer activity. Like *MacPaint*, Thomas uses *KidPix* to create graphics, though with color and with tools that also offer interesting sound effects (such as the sounds of a pencil "scratching" against paper and a very "liquidy" sounding paint bucket.)

There are two activities that dominate Thomas' time in *KidPix*. The first activity, called "hidden picture," is built into *KidPix*. "Hidden picture" is a special erase feature where one uses the eraser to uncover a picture hidden "below." Thomas has spent so much time with this feature that he is able to identify the picture soon after the first details emerge. The second activity is an original creation by Thomas. Thomas draws random lines all over the screen, though most are vertical. He then quickly changes to the fill bucket tool. Then carefully and methodically, he fills in each small space with paint until the entire screen is virtually covered, similar to a variation of his "paint the wall" goal with MacPaint. Interestingly, he has extraordinary fine motor control and can "aim" the fill bucket to pour paint into spaces that are only a few pixels wide. Thomas seems to find this activity exceedingly relaxing.

Custom Designed Software: Toward Microworlds

All of Thomas' experiences with *KidPix*, *MacPaint*, and *HyperCard* were worthwhile. He was engaged in imaginative play using a variety of tools and he was continually learning new tools as well as new ways to use old tools. On the other hand, his experiences were quite haphazard and there was little opportunity for him to explore many fundamental concepts of language and mathematics. There were also some basic skills that he was having much difficulty with, such as the concept of direction and discriminating between left and right. In response, I began to develop some activities for Thomas in which he would be less likely to become distracted by a myriad of functions and tools. The design methodology I used was really a hybrid of all my design knowledge, though the methodology of rapid prototyping comes closest to describing it (see Tripp & Bichelmeyer, 1990, and Rieber, 1994b, for more detailed discussions of rapid prototyping in instructional design). Consequently, the goals of the activities often emerged based on how he reacted to them. The computer authoring tools at my disposal allowed me to quickly develop a prototype to try out with Thomas in order to discover if the idea was worth pursuing or abandoning. All of these activities were created in a very short period of time, usually less than two days, and fine tuned based on Thomas' success, interests, and frustrations. The software will be briefly described in the next sections.

Sour Apple. Sour Apple is a mathematics game to help Thomas develop basic number theory. The goal of the game is simply to eat all of the apples. As shown in Figure 1, the game is played by clicking on the numbers one, two, or three. When one of the numbers is chosen, the number name is spoken by the computer and the appropriate number of apples are "eaten" (i.e. each shrinks to a vanishing point at their center). An important feature occurs

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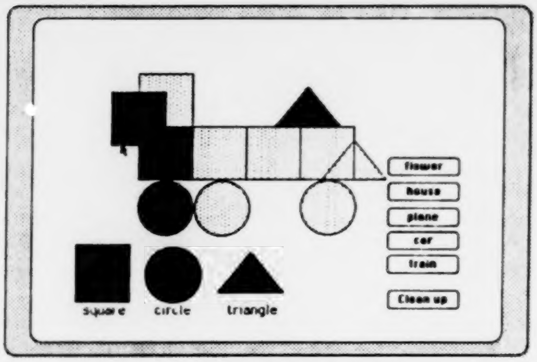

Figure 2. Snapshot of the screen during *Shape Art.*

towards the end of the game. If one chooses "3" or "2" when fewer apples are actually left, the computer says matter of factly "But there are only two [or one] apples left!" while displaying this text on the screen. When all the apples have been "eaten," the computer says "You ate all the apples!" again with the text displayed on the screen. The decision to display the corresponding text was based on trying to reinforce the concept that written symbols (i.e. words) carry meaning.

Though Thomas chooses to play *Sour Apple* on a regular basis, he rarely plays it for extended periods of time. He will usually play one or two rounds and then quit to choose something else. His typical strategy is to choose to eat only one apple at a time. He only occasionally chooses to eat two apples and he rarely chooses three apples. The original inspiration for *Sour Apple* came from a classic math game called *Poison Apple* which I had transferred to the computer about ten years ago (though I preferred to call it "sour apple"). I played the game with Thomas once and although it was filled with prompts and messages that he found confusing and annoying, he continually asked to play the game again. Consequently, I designed this version to meet his request and expectations.

Shape Art. This is one of Thomas' favorite games. There are many purposes to *Shape Art*, including spatial manipulation, language based on sight word vocabulary, and simple problem solving which stresses part to whole reasoning. *Shape Arts* builds on Thomas' graphical interests and abilities by allowing him to draw pictures. However, instead of drawing with a pencil or brush one draws pictures with the three basic shapes of circles, squares, and triangles. As shown in Figure 2, there is a "well" of a limited supply of these three basic shapes on the bottom of the screen. One must click, hold, and drag one of the shapes to any location on the screen, a skill which Thomas, surprisingly, had little difficulty mastering. Thomas has the choice of drawing with the figures on a blank screen or choosing a "picture outline" corresponding to the buttons on the right side of the screen. When a button is pressed, the computer pronounces the word on the button, such as "train," and an outline of a train appears. The pictures can all be made by combinations of the three basic shapes. Thomas enjoys moving the appropriate shapes into their respective places. In addition, the parts to whole problem has a puzzle-like quality that Thomas seems to enjoy. One feature of *Shape Art* that Thomas particularly enjoys is the "Clean up" button. Its function is to put all of the shapes back to their original positions (using animation) and also erasing the screen.

One intended goal of *Shape Art* is to provide Thomas with an interesting environment in which he can explore simple language, again in the hope that he will associate printed words with meaning. A future goal is to find activities in which Thomas can build a sight word vocabulary through meaningful interaction with single words. Part of this motivation is due to Thomas' inability to make any sense of a phonics approach to language. The use of a heavy phonics approach even with normally functioning children is continually debated among language educators. In Thomas' case, phonics has become a psychological obstacle which I speculate is based on his frequent failure in the public schools. Thomas seems to "turn off" or "tune out" any attempt to teach phonics.

Treasure Hunt. The purpose of this activity, as illustrated in Figure 3, was to provide Thomas with a "left vs. right" microworld. The microworld is presented in a game-like context based on the fantasy of pirate treasure. This context was chosen based on Thomas' fondness at the time for the movie "The Goonies." When the graphic of either hand is clicked, the computer says either "left" or "right" and the boat moves one step toward that direction. The most obvious goal is to maneuver the boat toward the treasure at the bottom while also avoiding the pirates (as indicated by the "cross bones" flag) or sea monster. The graphics of the treasure, pirate flag, and sea monster are placed at random locations at the start of each round of the game. Of course, another goal might be to aim the boat

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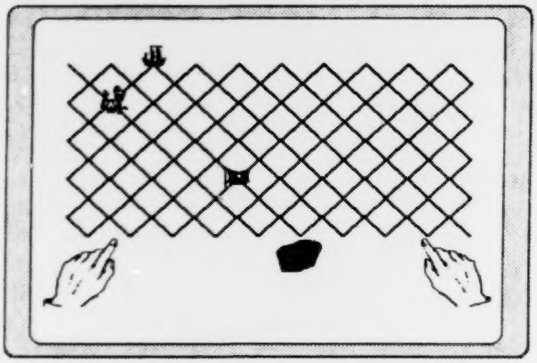

Figure 3. Snapshot of the screen during *Treasure Hunt.*

toward the pirate or monster. In either case, the value of the interaction remains the same. This activity was a short-lived favorite with Thomas. Though he interacted with he often at first, he rarely chooses it anymore. His interest in the fantasy context has apparently dwindled. Of course, he hasn't watch the movie lately either, so perhaps that might trigger renewed interest in this game.

Tom's Train. The inspiration for this activity was setting up a toy train under the tree one Christmas. Thomas enjoyed playing with the toy train and learned to adequately master its controls. After Christmas, the train was put away. Afterwards, Thomas often asked to play with the train. But since it took so much effort to set up coupled with it needing an excessive amount of floor space in our tiny house, there was little incentive to bring the train out. I decided that the train might be a good fantasy context for Thomas based on his interest. My goals for this activity were very fuzzy, though two goals dominated my thinking early on. The first was that I wanted an activity in which Thomas would have to think several steps ahead to accomplish a task. Such ability to plan for the future is critical in problem-solving. Keeping one future task in mind while performing another task is trivial for most children of Thomas' age and adults but very difficult for Thomas. The second goal was to continue to encourage Thomas to recognize meaning from abstract symbols.

The activity begins by having a trolley-like train enter the track. The motion of the train can be controlled two ways: first, by changing the direction that the trolley will take when arriving at any of the several gates; second, the speed of the trolley can be controlled as well, though this function has never been recognized by Thomas. In Thomas' first experience with an earlier prototype, there was no clear goal to the activity other than watching the train go around the track. This was of little interest to Thomas. I quickly developed a second prototype, as shown in Figure 4, in which I added "tunnels." We had played with makeshift tunnels with the real toy train at Christmas, so Thomas was familiar with the concept. In addition, he really enjoys going through tunnels when driving in a car. He first saw the second prototype by watching me first play the game. I immediately said that I wanted the train to go through

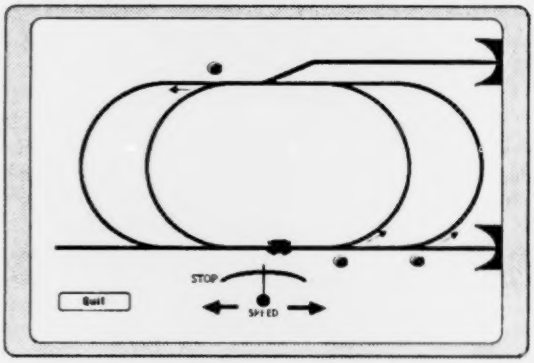

Figure 4. Snapshot of the screen during *Tom's Train.*

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the tunnel and he immediately found this goal interesting enough to want to pursue.

I was amazed how difficult Thomas found the task of relating the abstract symbol of an arrow head indicating "future direction" in this game. Fortunately, he persevered and continued to experiment, haphazardly at first. Of course, if one studies Figure 4 for a moment, it is clear that there are *two* gates that must be changed to get the trolley to go through the tunnel. Thomas finally succeeded in this fairly complex task. Interestingly, he will now choose this program, quickly make the trolley go through the tunnel, and then quit the program. This activity is ripe for adding other goals and tasks, such as picking up and dropping off passengers.

Ghostbusters. This is the most recent activity I have developed for Thomas. Its goal is to find as highly a motivating context for Thomas to explore written language as possible. As per the activity's title, its theme is the movie of the same name and it was chosen simply because it is one of Thomas' most favorite movies. Using Apple's QuickTime video protocol, key scenes were digitized. The scenes I chose were based on my interaction with Thomas as he watched the movie — these were some of the scenes he found most memorable. All of the scenes but one are highly verbal with dialog that Thomas "absorbed" from watching the movie, such as Bill Murray's "He slimed me!"

When any of the four scenes are chosen, the entire scene is played, both video and audio. This is followed by the lines of dialog appearing to the side of the video window, which, when clicked, cause the video and audio corresponding to that line to be played. The other option is to interact with the scene through the slide bar at the bottom of the video window. The goal here was to provide a highly motivating reason to interact with the text lines again with the hope to promote the concept that print carries meaning.

Interestingly, at the start Thomas seemed to avoid all of the printed words. In fact, though Thomas has played *Ghostbusters* for about three months he is just beginning to interact more frequently with the text. In contrast, he quickly learned (by the end of the first session) how to manipulate the QuickTime controls to play the scene over and over, frame by frame, and backwards. Again, he does not interact with this activity for very long, preferring instead to sample it for brief periods. So far, he is focusing on key phrases and his most favorite to date is Dan Ackroyd's "Actual physical contact!"

There are still a few problems with the design of the interface. For example, Thomas gets confused about the need to press a "continue" button after viewing one scene to go back to the option to view any of the four scenes. The problem is with the software, not Thomas, and this needs to be changed.

Adventures in *The Playroom*

One of Thomas' recent birthday presents was another commercial product called *The Playroom*. The package has a series of activities which one chooses from the organizing graphic suggested in its title, a child's play room. The activities include simple math games, telling time, developing a "survival" sight word vocabulary, beginning letter sounds, a letter and word recognition activity resembling word processing, plus an assortment of other amusing activities. A particularly good feature of *The Playroom* is that it lends itself to creative exploration. One is rewarded by trying new things, though it is always easy to return to the "playroom" from an activity by clicking on the graphic of a "connecting door." Thomas' interest in *The Playroom* rivals that of *KidPix*; he spends about 80% of his computer time between these two packages with the remainder spent on the software I custom designed for him. A special cartoon character called "Pepper Mouse" is a central figure in most of the Playroom's activities (a small stuffed version of Pepper Mouse came free with the software). Thomas refers to *The Playroom* as "peppa mus."

There are too many activities in *The Playroom* to describe here, so only his favorite activity, "The ABC Book," will be briefly discussed. This activity uses beginning letter words (such as "U" for "unicorn") in a variety of fantasy contexts (such as a fairy tale castle, a barnyard, and a city street). When the user chooses any letter of the alphabet, the computer pronounces the letter and corresponding word and then "attaches" a picture of the word to the mouse. The user can move the picture around the screen and "deposit" it anywhere by clicking. Thomas spends extended periods of time interacting with this one activity alone. It has been among the most successful activities yet for Thomas in which language has been embedded in creative fantasy play.

Thomas as Navigator

One of the most interesting skills that Thomas has acquired is navigating effortlessly between software applications on the Macintosh desktop. It is hard to describe how this occurred and there is no magic "instructional plan" to share to make it happen with other children like Thomas. Over the course of the last two years, Thomas has just slowly assimilated simple strategies to achieve his "grazing" between all of the software at his disposal. Early after his cognitive breakthrough in understanding how graphical symbols could change the function of the mouse, he began to pay closer attention to how I would intervene to solve unexpected problems. For example, when working with *MacPaint*, he would sometimes accidentally cause a dialog box to appear. The user is expected to make choices or changes and then click on an "OK" button, at which time the user is returned to the application. Thomas

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apparently learned incidentally a rule like "When in doubt, click OK," by watching how I intervened to solve the problem.

This example and others were probably due to my care in always verbalizing my actions even though I never forced Thomas to pay attention. I would talk through my "double-clicking," "Quits" and "Shut downs." Thomas eventually picked these up not because he was *taught* these techniques, but because he was part of the computer culture and eventually these became relevant and useful to him. These techniques became *authentic* tasks for Thomas because they were the "secrets" to controlling the computer for his own use. I am sure that Thomas' understanding of these techniques remains vague, but that is really beside the point. His understanding of "double-click to open" for example is closer to "click repeatedly until something happens." Fortunately, all Macintosh software reacts consistently to these techniques and rarely "punishes" users who do not have precise understanding. Being vaguely right is good enough.

A Matter of Control

It is difficult to distill features that comprise Thomas' most successful everyday experiences, though his time with the computer is the most prominent example. In fact, there are very few other experiences in which Thomas seems to exhibit the same level of satisfaction. Other examples include pouring himself a glass of soda, fixing a peanut butter sandwich, riding his bike at the park, drawing with pens and markers, and imaginative play with certain toys. These are not general examples, but the "long" list of specific activities in which Thomas excels. The closest common denominator to these activities, I believe, seems to be that Thomas feels totally in control. He is expected and able to exercise complete freedom in how he chooses to explore these environments.

When Thomas is working on the computer, he is in charge. His success in navigating around the Macintosh desktop to begin and quit activities has fueled the tendency to take other chances to learn new commands and functions. He has also been rewarded for his exploration. When working with the computer, I believe that Thomas considers himself to be combination of tinkerer, inventor, explorer, and trailblazer. This is his medium not only for expression, but also for risk taking. Another software package that Thomas has greatly enjoyed that has likewise encouraged a playful, exploratory attitude is the "living book" called *Just Grandma and Me*, in which the "Little Critter" book by Mercer Mayer comes alive through animation and sound on the computer. There is wonderful irony in knowing that Thomas finds comfort and confidence in a machine that often threatens and intimidates other normally functioning adults.

Conclusions

It is unclear whether any of Thomas' learning with the computer will transfer to other situations. For the moment, this does not seem very important. What is important is that he *is* learning and finding the computer to be an engaging medium. It is also important that all of Thomas' learning is necessarily incidental, though admittedly there is external intervention on my part to provide him with custom designed microworlds that will give him special opportunities to explore certain domains. Despite this external guidance, his learning remains incidental because he controls what he explores and what the goal of the interaction will be. He does not play "Sour Apple," for example, to learn about simple counting and number theory, though why he does choose to play it is unclear. He may just enjoy watching apples disappear or find satisfaction in completing a task. I wish I had more insight to his behavior, but I am satisfied by his satisfaction.

Also unclear is where Thomas' abilities end and the computer's abilities begin as they interact with one another. I feel that their cognitive partnership is a concept worth reflecting upon. Thomas is engaged in what Salomon & Globerson (1987) have called "mindfulness" -- deliberate, thoughtful, and challenging activity which requires much effort. Some might call this "work." Though the term has many negative connotations, those adults who love their work understand that there is little that can give them more satisfaction, despite how difficult it may be, no matter what occupation or profession it may involve. This is the kind of work that Thomas is engaged in. Whether or not Thomas will find a way to channel his mindful work to become an independently functioning adult in society remains to be seen.

Ironically, Thomas's difficulties in meeting the expectations of society (including the educational system) is both his greatest liability and his greatest asset. On one hand, the people who matter most in Thomas's life are concerned about his future. As Thomas' parents, my wife and I worry about the possibility of his lifelong dependence on us. We also worry that we are not giving enough attention to our daughter. Now that Thomas is 11 years old, we realize it is a distinct possibility that he will never be able to function apart from us or professional caretakers. Thomas' many classroom teachers over the years had have a wide range of concerns as well. Many, if not most, have worried about his lack of academic progress and socialization skills. The most well intentioned have focused on "survival" skills, such as crossing streets and grocery shopping, to increase Thomas's ability to function independently in society. The least well-intentioned have tolerated Thomas at best and belittled him at worst, unashamedly bringing to the surface the extent of his differences. It is tempting to say that Thomas does not know how as yet to "fit in" to society and the classroom. However, it may be more accurate to say that society and the classroom do not "fit in" with Thomas. So, on the other hand, Thomas may not feel as shackled by the demands of society either because he is not aware of it, does not recognize it, does not comprehend it, or perhaps, *does not accept it.* Thomas's intellectual and social functioning still remains virtually ego centered and it is unclear whether he will ever be able to empathize with others. In some respects, this is a very enviable position. Society's demands have not reached Thomas as yet, and perhaps they shouldn't.

The most recent progress Thomas has made has been social in nature. Slowly over the past year, he has showed clear signs of seeking other children his own age with which to interact. He is attending public school again and, so far, all is going very well. The reason for this is complex and multifaceted. Fortunately, several important attributes are working in Thomas' favor. First, I believe that he is seeking out interaction with other children. However, the nature of the interaction is quite fragile. Fortunately, his teacher's personality seems a perfect match for Thomas' plus she has clearly taken much time and effort to try to understand him. She deserves much credit for promoting a classroom where mutual respect is the rule and for providing social and intellectual experiences derived from the children themselves. The cognitive "awakening" that Thomas is experiencing through his partnership with the computer is being matched by a similar social "awakening." He seems to be in the process of exploring his relationship with society. What seems to be most crucial is that he has been given a reasonable level of control over that exploration while being rewarded for taking initiative. Whether this turns out to be a trend or a temporary aberration remains to be seen.

Finally, I have not stressed enough in this paper how much Thomas has taught me about design as I think this is a topic for discussion at a later time. I often remark in my design classes that working with children, especially young children, is among the best ways to learn about learner-centered design, even if one's interest is primarily with adult populations. There are at least two reasons for this. First, young children are generally not able to bring to the learning environment as many strategies to make up for poor design. Normally functioning adult users, if motivated enough, can bring all types of learned cognitive strategies and prior knowledge to the table. Second, young children will not tolerate designs that are poor, irrelevant, or meaningless, thus making for very quick feedback to the designer. Thomas has been a co-designer in all of the computer activities I have developed for him, even though he does not know it. The starting point for these custom built activities have been Thomas' interests and abilities combined with much speculation on my part about where he might be headed next. By involving Thomas in the design process at the beginning, he has largely determined the "instructional objectives."

I end this paper with a simple story of success. Any small success is a great achievement with Thomas. Just recently, while eating out at a restaurant, Thomas read the word "exit," his first sight word besides his name. He immediately began talking about Pepper Mouse.

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Footnote

[1] Thomas had been having many unsuccessful experiences in the public schools. My wife and I came to the conclusion that the schools were failing to meet Thomas' needs and rather than try to "fight the system," we decided

it was in Thomas' best interest to home school him for a period of time. My wife assumed most of the home school responsibilities. We also enrolled Thomas in a Montessori school for a short time. This school seemed particularly well suited to Thomas given the nature of the Montessori method where students have much freedom to choose activities that interest them. In addition, Maria Montessori's methods were historically founded on her work with the mentally retarded. For two months, Thomas seemed to be doing well. Then, on the morning of the first day of the month, while Thomas was getting ready for school, the school's owner called to inform us that, unfortunately, Thomas had been "dismissed" from the school and that he could no longer attend effective immediately. The owner worried about what effect Thomas' presence was having on the other children. Consequently, Thomas was home schooled for the remainder of that year as well. This example is not meant as an indictment of Montesorri schools, but it well represents the general attitude we have found among professional educators. There is much talk about *inclusive* environments, but little motivation and understanding to promote situations in which children with exceptionalities are considered *part* of the school culture. This is unfortunate because normally functioning children have as much to gain as well.

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Qualitative Research on Level III Interactive Video with Generic and Returning Registered Nurse Students

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Abstract: Level III interactive video is a flexible, hi-tech learning modality that has been utilized with both undergraduate generic and returning registered nurse students. Past studies have shown that level III interactive video can enhance education in a variety of settings with a variety of learners. Ongoing research into the effect of level III interactive video on nursing education is imperative. After a review of the literature, it was evident that there was a need to assess level III interactive video from the student's perspective. Therefore, a qualitative approach was indicated to determine the students' perceptions with regard to their learning needs, personal needs, and ability to carry out the nursing process. A pilot study was conducted and the interview schedule was revised. Each subject will complete the same level III interactive video module and interview schedule. This funded research is in process.

Introduction

Advances in instructional technology have made it possible to utilize interactive video in the nursing education arena to enhance and augment clinical nursing experience. Given the current state of affairs in nursing education, limited clinical experience with decreased access to diverse clients, interactive video appears to be the answer for the future. Interactive video combines the power of the computer with the visual and/or auditory capabilities of the videodisc. The literature has portrayed interactive video in a favorable light from an educator-based perspective (Lanier, 1986; Kozma, 1990; McNeil & Nelson, 1990). However, before we begin to integrate interactive video throughout nursing curriculums, it is imperative to determine its effectiveness from the learner's perspective.

Andragogical, or adult learning, principles apply to nursing students; as adults, they build on and relate to past experiences they have encountered. To assess the potential of interactive video with the adult learner, one must recognize that not all adults are the same. The adult education literature supports the view that there are levels of difference within age groups of adults (Brookfield, 1990; Darkenwald & Merriam, 1982). Whereas andragogy provides a conceptual framework stating that all adults require high levels of input into content that is relative to their needs, course designs that are conducive to learning, and evaluation of their learning needs and the activities associated with learning. It is still a question as to how early in the learning process various adult learning groups should be involved with extensive input. The generic nurses are typically a younger population, often having familiarity with computers and communication technology. The returning registered nurse students are a comparatively older group, typically with high motivation and a rich "reservoir of experiences" (Knowles, 1980, p. 45). In the future, for instance, can we anticipate that the high comfort level of generic students with technology will make them ready candidates for interactive video? Will it be the case that they will need more repetition and structure through the interactive video due to their more limited experiential base? On the other hand, will returning registered nurse students respond more enthusiastically to interactive video due to their high level of motivation and wealth of experience or will they first need to receive hands-on computer training? Which group will respond better early, which group will respond better later, and what

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strategies will the field need? From an andragogical stand point, interactive video is a learner-driven educational modality; the learners access and view learning segments based on their learning needs. The issue to be investigated is how well the two groups will respond to the andragogical capacity of interactive video and the extent to which the field needs to be sensitive to the addition of this technology with these two groups of students.

Specific Aims

The purpose of this study is to determine the extent of andragogical effectiveness of interactive video from the learner's perspective. The learners will be interviewed according to andragogical criteria to determine if their learning needs have been met. These criteria are learner-driven and include whether the learning environment, activities of learning, and participative learning, through learner control of the interactive video presentation, met their needs. This proposal suggests a qualitative descriptive study is needed since it is important to determine the learners' perspectives regarding this innovative instructional technique. This study will provide learner-based information that nursing educators, who deal with adult learners, need in order to assess the integration of interactive video into entry level nursing education and/or professional continuing education for nurses.

The specific aims of this study are:

1) To delineate the undergraduate nursing students' perceptions of instruction via interactive video versus traditional classroom lecture format.
2) To identify whether the visual presentation contained within the Interactive video enhanced the textual format for purposes of learning on the part of the student.
3) To identify students' needs (learning, personal) that are met with the use of the interactive video instruction and may not be met by traditional classroom lecture format, based on the learners' perceptions.
4) To determine whether the Interactive video learning modality enhanced students' sense of competence with respect to carrying out the nursing process, based on the learners' perceptions.
5) To contrast generic nursing students' and registered nurse students' perceptions of the effectiveness of interactive video from the learners' perspective with respect to andragogical criteria.
6) To make specific recommendations to the field on the effectiveness, desirability, and use of interactive video with generic and registered nurse students.

The long term goal of this qualitative descriptive study is to provide a basis for designing a model for integrating clinical components in nursing education via interactive video. This model will be utilized to develop more comprehensive studies focused toward designing and testing an intervention that nursing educators can implement to facilitate clinical nursing education.

Background And Significance

Nursing education is changing. It is a challenge to provide students with the clinical experience necessary to meet their learning needs. As acute care settings become more specific, the students' exposure to diverse clients during their clinical rotation is decreasing. This limited experience necessitates the use of innovative teaching techniques such as interactive video. Interactive video combines the power of the computer with the visual and/or auditory capabilities of the videodisc. According to Sweeney and Gulino (1988), "the videodisc brings to the screen clear views of the patient, the equipment, or the setting, rather than relying on the printed word or computer generated graphics to get the message across" (p. 158). Interactive video is self-paced and learner controlled. Based on their learning needs, the learners control their own interactive video experience by utilizing the computer. Built in navigational controls facilitate the students' individualized movement throughout the learning module. According to Pogue (1988), "learning theory supports the premise that the major advantages of the computer as a tool of instruction are its ability to allow us to provide interaction and individualization as an integral part of the instructed process" (p. 95). Roberts (1981) contends that most adults do best in self-paced situations given the internal nature of learning. Gayeski and Williams (1985) have identified four levels of interactive video; for the purposes of this study, interactive video will refer to Level III interactive video. Level III interactive video involves constant angular velocity (CAV) format videodiscs controlled by an external

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computer connected to a commercial grade laserdisc player (Gayeski & Williams, 1985). The computer portion of the program can readily be rewritten, or repurposed, for a specific instructional use. Most interactive videodiscs on the market today are Level III applications.

Interactive video presentations have been shown to be well received by people with no familiarity with computers and in various professions and occupations: dairy farmers (Debloois, 1981); military personnel (DeBloois & Woolley, 1981); white collar workers (Main, 1984). The literature remains mainly educator-driven (Kozma, 1990; McNeil & Nelson, 1990; Lanier, 1986). Kozma (1990) described interactive video as cost effective in materials and personnel, particularly when safety is a factor in learning content of disciplines like chemistry or health. According to the work of Lanier (1986), "interactive video is time efficient; the user can go through the program at his or her own pace...Learning specific tasks takes an average of 30-35% less time with the disc than with older methods. Retention of material is better" (p. 37). In a meta-analysis of interactive video instruction research of the past 10 years, McNeil and Nelson (1990) noted an overall mean achievement effect of 0.530, indicating that interactive video is an effective form of instruction. The literature also supports the belief that interactive video aids in clinical decision making (Clark, 1984; Sweeney & Gulino, 1988; Weiner, 1988; Hodgin, 1986). According to Brown and Minton (1993), Classroom 2000 is a state-of-the-art technology project to enhance employability skills. They contend that, "by repeated consideration of the behaviors and attitudes appropriate in the workplace, students learn to understand how employers think and how, as workers, they must behave on the job in order to retain employment" (p. 67). Clark (1984) reported that interactive video instruction, utilized by the American Heart Association, trained students in CPR in one-third of the time needed with the conventional method and the retention rate doubled. These projects (Clark, 1984; Brown & Minton, 1993) demonstrate the impact technology can have on the cognitive, affective, and psychomotor learning domains. It is easy to extrapolate the use of technology, such as interactive video, into nursing education since nursing practice encompasses all three domains: cognitive, affective, and psychomotor. Nursing education is an area in which interactive video could be utilized to enhance, augment, and/or replace traditional forms of instruction (Kozma, 1990). Sweeney and Gulino (1988) state that, "microcomputers offer tremendous potential to the clinical educator. They are especially suited for teaching applied skills when coupled with a videodisc player" (p. 158). Interactive video had been described as most effective in providing challenging simulations that aid in developing problem solving abilities and decision making skills (Hodgin, 1986; Weiner, 1988). As clinical objectives become more difficult to meet for every student, the high-tech, flexible, learning modality of interactive video could be utilized to provide all students with the same needed information and experiences. The interactive video learning modality facilitates the learners' grasp of the material while increasing their level of retention (Clark, 1984).

According to Dover and Boblin (1991), it is necessary to prepare nursing students for the ever changing health care environment. Maternal/child health nursing is a challenging area for nursing educators; the time spent in labor and delivery is limited and the variety of births observed is not predictable. This project would utilize interactive video to review and expand the students' encounters with birth experiences. This learning modality is applicable to both the registered nurse and the generic undergraduate nursing student (Sweeney & Gulino, 1988). Nursing is a profession based on practice encompassing cognitive, affective, and psychomotor skills. The nursing students must be able to assess and cognitively and affectively create a holistic composite of their clients from which to draw conclusions or formulate nursing diagnoses, goals and objectives. They must then choose and, using their psychomotor skills, carry out appropriate nursing interventions to facilitate the client meeting the established objectives. They then evaluate both the effectiveness of the nursing care and the client's progress toward the designated goals and objectives. Interactive video would address the learners' needs for application driven content as well as the andragogical criteria which are believed to facilitate and enhance adult learning. According to Knowles (1980), "the way to produce competent people is to have them acquire their knowledge (and skills, understandings, attitudes, values, and interests) in the context of its application" (p. 19). This instructional technology enables the students to work through actual client situation simulations via videodisc and permits 'safe' problem solving outside of the clinical setting. This promotes problem-solving abilities and facilitates clinical competence. Bandura and Cervone (1986) feel that as students extend their powers of critical thought there is an increased sense of self-efficacy and self-worth. They state that these feelings facilitate learning and the ability to apply it.

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The conceptual framework for this research project arises from Knowles (1980; 1984) theory of andragogy that both empowers the learners' selection of relevant content and enhances self-directedness. Knowles defines andragogy as "the art and science of helping adults learn" (1980, p. 43). According to Knowles, it is the foundation for developing the competence to engage in lifelong, self-directed learning. He describes seven phases in the andragogical process: "1) establishment of a climate conducive to adult learning; 2) creation of an organizational structure for participative learning; 3) diagnosis of needs for learning; 4) formulation of directions of learning (objectives); 5) development of a design of activities; 6) operation of the activities; 7) rediagnosis of needs for learning (evaluation)" (p. 59). Knowles contends that learning is an internal process involving the total person. He describes the learning-teaching interactions as the recognition of adult students' needs and the development and use of superior principles of teaching. Learners accumulate an increasing supply of experience that serves as resources for their own learning. The learning process is related to and makes use of these experiences with the learner actively participating. The critical function of the teacher is to create a rich environment in which students' motivation to learn is enhanced since the critical part of learning is the interaction between the learner and his or her environment. According to Williams and Benedict (1990), nursing faculty members must "recognize their students' rich and diverse knowledge and experience in designing learning experiences which are consistent with adult learning theory" (p. 201). The principles of andragogy must be integrated into nursing education in order to enhance nursing students' learning experiences. Using interactive video enables the instructor to create and/or choose multimedia learning environments in which the students can interact. The student interaction is based on the students' needs for information and can be individualized by the choices they make.

Our study is designed to determine the andragogical learning conditions of interactive video from the students' perspective. The assumptions are that the learners' learning needs as well as their personal needs will be met. The learning needs of the student are addressed in this modality since the navigational tools provided permit them to view any portions of the learning module they choose. This facilitates entry-level adults or generic nursing students as well as returning registered nurses continuing their education. The generic nursing students' learning is augmented by the use of interactive video. This modality could maximize their educational experience by facilitating the integration of theory and clinical practice skills and greatly enhance their educational experience (Sweeney & Gulino, 1988). Using interactive video would provide the returning registered nurse students with the opportunity to review clinical components previously experienced in their basic nursing programs while synthesizing the theoretical concepts of their baccalaureate education. Adult students' personal needs for self-paced, flexible, instructional modules should be easily addressed with the flexible, hi-tech modality of interactive video.

Methods

Research Design

This qualitative descriptive study will be carried out by means of one semi-structured interview consisting of open-ended questions to explore the perceptions of nursing students using interactive video. Rizzolo (1990) conducted a Delphi study exploring the factors influencing the use of interactive video. Rizzolo concludes, "the place of [interactive video] in all educational settings has not yet been determined" (p. 157). Kozma (1990) believes that interactive video is particularly beneficial in the discipline of health education where safety is a factor. There have not been great strides made since Hannafin (1985) recommended that learner control and the positive attitude toward interactive video be explored. This descriptive approach facilitates the data collection with a minimum of investigator bias while permitting the nursing students to express their feelings toward interactive video (Berg, 1989).

This study is designed to answer five research questions:

1) What are the perceptions of undergraduate nursing students with respect to the interactive video learning modality versus traditional classroom lecture format?
2) Are the visual presentations contained within the Interactive video learning modality enhancing to the textual format as well as to student learning?
3) What needs (learning, personal) of the students are met with the use of the interactive video

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learning modality?

4) What is the effect of the interactive video learning modality on the students' sense of competence with respect to carrying out the nursing process?
5) Are there qualitative differences between the generic nursing students' and the registered nurse students' perceptions on the effectiveness of interactive video?

Sample

This opportunistic and purposeful sample will consist of six generic undergraduate nursing students from the University of Pittsburgh and six registered nurse undergraduate students returning for their baccalaureate nursing degrees at Penn State University. In addition, one generic nursing student and one registered nurse student will participate in the pilot phase of this study. The descriptive nature of this study and its method of inquiry support the adequacy of a sample size of twelve. Qualitative inquiries, according to Lincoln and Guba (1985), need only be large enough "to detail the many specifics that give the context its unique flavor" and "to generate the information upon which the emergent design can be based" (p. 201).

Measures/Instruments

One semi-structured interview consisting of open-ended questions will be employed to facilitate discussion regarding interactive video and traditional classroom lecture format from the perspective of the nursing students. The interview schedule will be loosely derived from the literature and will be evaluated for face and content validity by experts in the areas of qualitative research and interactive video. In addition, the interview schedule will be piloted on two undergraduate nursing students, one generic nursing student and one registered nurse student.

Procedure

Each participant will complete the interactive video program, *Perinatal Family Care: A Learning Module on Intrapartal Nursing Care*. The semi-structured interview will be scheduled within two weeks of the participant's completion of the interactive video program. The interactive video and interview schedule will be tested on two undergraduate nursing students, one generic and one registered nurse student. After revising the interview schedule, appointments will be made to meet with each volunteer to obtain written consent for his/her participation in the study, answer any and all questions he/she may have, confirm the audio taping of the interview, review confidentiality measures, and schedule their interactive video session. Once the interactive video session is arranged, the interview will be scheduled.

Plan for Data Analysis

Reliance on the transcribed semi-structured interviews, rather than fixed-choice instruments, permits openness to features of andragogical processes that may not be anticipated in advance. Consequently, the data will initially be somewhat unstructured. The necessary structure for data analysis will, however, be provided during analytical procedures which will include organizing, coding, categorizing, and generating themes and patterns. The transcribed interviews will be analyzed by the research team employing content analysis techniques prescribed by the literature (Polit & Hungler, 1983; Fox, 1982). The inter-coder reliability formula specified by Miles and Huberman (1984) will be used to compare the data analyses of the research team members. Reliability of data analysis will also be enhanced and made less cumbersome with the use of Ethnograph (Seidel, Kjolseth, & Seymour, 1988), a computerized system for coding, filing, retrieval, and review. Four of the study participants, two generic nursing students and two registered nurse students, will be contacted to read and validate the team's findings. An aggregate, narrative description of the interactive video experience, derived from the content analysis process, will be given to the students for verification.

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Utilizing CAD Technology to Enhance Multicultural Awareness

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Abstract: Universities across the nation are stressing the importance of integrating multicultural experiences into the classroom. Faculty at Florida State University and Colorado State University have developed three creative ideas incorporating the use of computer-aided design and multicultural experiences into their computer aided design (CAD) courses. As a result of these projects, student appreciation of diverse cultural influences increased and design solutions were improved.

Introduction

Universities across the nation are stressing the importance of integrating multicultural experiences into the classroom. Within interior design and housing programs, many innovative ideas are developing as a response to this demand. At Florida State University and Colorado State University, design faculty have developed three creative ideas incorporating the use of computer-aided design (CAD) and multicultural experiences into the CAD lab. Although these projects could be incorporated into any design course, CAD systems allow students to develop a motif/image, store it as a symbol, and insert or manipulate it as desired. This paper will discuss the multicultural projects, the benefit to the students and the enhanced results of the experience.

Background

International concerns along with multicultural sensitivity are of great concern to business and education today. Guerin (1991), in an article addressing the future of design education, lists international concerns as one of the top issues facing design education in the 21st century. She states, "contextual design with cultural sensitivity is an important component of interior design education." Henry Ferguson (1987), explains the importance of learning about ones own culture and how that relates to acceptance of other cultures. He states, "by knowing about his culture, one becomes intellectually and spiritually free." Naisbitt and Aburdene (1990), point out the although we may be evolving into a world economy, there are unmistakable signs of a powerful countertrend: " a backlash against uniformity, a desire to assert the uniqueness of one's own culture and language". Professions that interact internationally, or have international clients, such as interior design, must emphasize intercultural sensitivity, awareness, and knowledge about foreign establishments (Guerin, 1991).

Preparing professionals who can address the needs of a culturally diverse population is a significant national challenge for all educators. While it is still on the periphery rather than integrated to the curriculum in most schools and colleges, multicultural education has made significant inroads in curricula within the last two decades (Banks, 1993). Some of the nations leading colleges and universities have either revised their general core curriculum to include ethnic content or have established an ethnic studies course requirement. For example, Florida State University requires all freshman to take six semester hours of multicultural courses (FSU Bulletin, 1991-92). However, Ferguson (1987), argues that when multicultural studies are conveniently relegated to "World Culture" classes, students view them as "beside the point". At a workshop at the University of Florida, Renner (1989) mentioned the difficulty in persuading faculty members to internationalize their existing courses and feels the international dimension should be a natural part of any well-conceived major. Commitment to improving diversity at Colorado State University has high priority and is evident in the multitude to activities conducted to improve diversity (CSU Progress Report, 1991). In essence, multicultural education is a movement designed to restructure educational institutions so that all students, including middle-class whites will acquire the knowledge, skills, and attitudes needed to function effectively in a culturally and ethnically diverse nation and world (Sleeter & and Grant, 1988).

Multicultural education is not an ethnic or gender specific movement. It is a movement designed to empower all students to become knowledgeable, caring, and active citizens in a deeply troubled and ethnically polarized nation and world (Banks, 1993a). Five dimensions to multicultural education have been defined as 1)content integration, 2)knowledge construction process, 3)prejudice reduction, 4)equity pedagogy, and 5)and empowering school culture and social structure (Banks, 1993b).

The typical United States citizen has become difficult to describe. By the end of the 20th century, the Hispanic population will have increased by an estimated 21%, the Asian by about 22%, the African-American by almost 12%, and the white by a little more than 2%. Census statistics document a trend in population growth in which by 2020, Hispanic or non-white U.S. residents will have doubled and the white non-Hispanic population will not have increased at all (Henry, 1990). Immigration to the U.S. has steadily increased since 1960 and now exceeds one million per year (Statistical Abstract of the United States, 1992). In contrast to these major demographic changes, students attracted to the interior design professions continue to be predominately white female (ASID, 1992).

Process

Recognizing the importance of having diversity incorporated into existing classes and academic majors, three design projects were developed for use in two FIDER accredited interior design programs at Colorado State University and Florida State University. The goals of the projects were to expand the student's use of the computer, to study various cultures of the world and to heighten the student's awareness of how diverse their personal ancestral cultures are and how they contribute to the diversity of their university environment. This was to be accomplished without sacrificing the quality or altering the goals of the existing course. The details of projects are discusses below.

As a beginning CAD assignment, students were given the choice of creating a custom design for a door or entryway detail, a fabric, or an area rug. Three different experiences were developed with the emphasis on studying history and culture: a visit to the Aztec Exhibit in Denver, Colorado; researching Seminole Indians in Florida, and student research into their personal ancestry.

Colorado State University students were offered the opportunity to view the Aztec exhibit in Denver. Through the generosity of the Mexican people, nearly 300 artifacts which dramatically illustrated the rich cultural legacy of the Aztecs was shown in Denver, Colorado. At that time, with the North American Free trade agreement close to passing, it seemed appropriate for design student to study and appreciate the heritage of their neighboring country.

Florida State University students had the opportunity and the responsibility to learn about Seminole Indians. FSU uses the name Seminole and the school "mascot". The instructor felt strongly that students should not graduate without understanding who the "real" Seminole Indians where. In addition, the Seminoles have beautiful patchwork patterns that are used when they create clothing. These patterns are varied and made an excellent source of inspiration for students.

Both Florida State and Colorado State students were also given the opportunity to research their personal ancestry. Many students were well-informed regarding their own history, but others had a lot to learn. Students were encouraged to research back as far a four generations if possible. In all cases, cultural artifacts were gathered and incorporated into their custom designs which were developed on the computer using AutoCAD software. Students located common symbols and images from these cultures such as art,

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architecture, costume, textiles design, or other visual artifacts.

Students then used the computer to create, manipulate, and print their designs. AutoCAD drafting and design software contains a number of useful command that allow students to explore many design possibilities. The editing commands are especially useful for creative problem solving. The move, copy, array, mirror, scale, trim, and extend commands are just a few of the many editing options that allowed students to explore design alternatives. The design process is interesting to observe when students are creating using the computer. Students were encouraged to sketch while visiting the museum or library. From those sketches, students can begin to create and manipulate images on the screen. The create of blocks or symbols allows entities to be created and then inserted, rotated, and scaled. At Colorado State drawings are first created in AutoCAD, then transported to Animator Pro to add color, then to 35 mm slides as final output. At Florida State, students create two designs, the second being a variation of the first. This allows them to see the flexibility and adaptability of software. In addition, after researching their chosen topic, they wrote a 2-3 page summary detailing the source of their inspiration for the project. The paper enhances the reliability of their sources of information and discourages stereotypical designs that may have occurred without thorough research. Designs were then presented to the class with class discussion encouraged.

Summary

Through these assignments and activities, students increased their knowledge of design while learning more about their world. Specific results from the CAD projects showed a greater variety of designs and a richness and depth to the designs. This depth and richness had not been seen in previous semesters when the cultural research was not required. In addition, the class discussions during presentation were much more detailed and research-based than those in previous semesters. Following the presentation, students were asked to react to the presentations and recall something they had learned during the presentation. All students reported they had learned something they did not know about another culture and a majority learned more about their own backgrounds. As a result of these projects, student appreciation of multicultural influences increased and design solutions seemed to be a better quality as a whole due to the required research. University goals were successfully achieved by looking to the past and developing an appreciation of the diverse future.

In order to develop tools necessary to function productively in a pluralistic society, educators must move beyond awareness of multicultural differences and technical information to application of knowledge with diverse groups (DeVaney & Hughey, 1992). Students awareness of their personal multicultural differences is the first step to effective multicultural education.

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USING THE INTERNET IN MIDDLE SCHOOLS: A MODEL FOR SUCCESS

A Collaborative Effort Between
Los Alamos National Laboratory and Los Alamos Middle School

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ABSTRACT Los Alamos National Laboratory (LANL) developed a model for school networking using Los Alamos Middle School as a testbed. The project was a collaborative effort between the school and the Laboratory. The school secured administrative funding for hardware and software; and LANL provided the network architecture, installation, consulting, and training. The model is characterized by a computer classroom linked with two GatorBoxes and a UNIX-based workstation server. Six additional computers have also been networked from a teacher learning center and the library. The model support infrastructure includes: local school system administrators/lead teachers, introductory and intermediate hands-on teacher training, teacher incentives for involvement and use, opportunities for student training and use, and ongoing LANL consulting. Formative evaluation data reveals that students and teachers alike are finding the Internet to be a tool that crosses disciplines, allowing them to obtain more timely information and to communicate with others more effectively and efficiently. A lead teacher's enthusiastic comments indicate some of the value gained: "We have just scratched the surface. Each day someone seems to find something new and interesting on the Internet. The possibilities seem endless."

I. PROJECT BACKGROUND

Motivation

The world of computer networking is opening doors to vast and wonderful classroom resources. Networking technology has advanced rapidly, and networking in the schools has been and, it appears, will continue to be implemented at an increasing rate. Five years ago, little potential existed for using internetworking in schools. Now, in 1994, the advantages of using networking technology in education are readily apparent. Libraries, universities, national laboratories, corporations, companies, and classroom teachers are sharing or making information and resources available through computer networks. The potential for our students is limited only by imagination. As Newman (1993) stated, "computer networks hold the key to the large-scale implemenation of school technology."

A national goal is to have every public school connected to a national information highway by the year 2000. Is the nation prepared to network all public K-12 institutions in the United States within the next six years? To meet this national goal, we must know what is working and what is not working about hardware, networks, software, curriculum integration, structuring issues, maintenance, and support. We must document the lessons learned to avoid reinventing the wheel and to leverage federal and state money effectively.

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History

In early 1993, Los Alamos Middle School (LAMS) used an existing Apple Macintosh-based computer lab with a local area network (LAN) to begin a new technological effort. Mr. Trottier, the LAMS principal, discussed with Los Alamos National Laboratory (LANL) the possibilities of designing a new network and obtaining help with connection to the Internet.

In 1993, LANL staff assisted LAMS teachers in this effort. The Los Alamos School District additionally supported this project by providing the funding to purchase equipment and software.

Many schools are becoming "connected;" however, being able to use that connectivity effectively is difficult for classroom teachers. Connie Stout of T-Net, a Texas networking effort, summed it up very well when she said: "Fear of the technology, inadequate funding and support, lack of adequate reasons to use the network, lack of access to telephone lines, and lack of time in the day are just a few of the hurdles that must be overcome before these networks will be used by PreK-12 educators." (Apple Classroom of Tomorrow Project)

There is a clear need not only to make networking technology and information available to the schools but also to provide training, software tools, and interfaces to make that technology and information readily and easily usable by our educators. LANL staff and LAMS teachers in this effort all agreed that the technology installation was just one part of the integrated educational technology picture. Instruction about available resources, how to access them, and how to use them easily and effectively is as important. Backed by the principal and supported by the lead teachers, we decided that training sessions should be developed to provide instruction for *all* the teachers and staff at the middle school in the use of the new technologies and the Internet. LANL staff members designed two instructional sessions (delivered multiple times), provide consulting support, and are planning additional training sessions. The LAMS lab directors/lead teachers are also designing and teaching additional sessions and providing lab time and assistance for the teachers. The results have been very rewarding, and feedback from the teachers has been very positive.

We want to share what we have learned from the middle school project with other schools and people interested in school networking, connecting to the Internet, or using Internet connectivity to a better advantage.

II. A MODEL FOR SCHOOL NETWORKING

Goals

A goal has been set by the federal government for all schools to be connected to a national network within the next six years. Yet, there are very few documented, feasible, and validated models of school networking for administrators and planners to follow. The goal of this project was to establish such a model, building upon both school resources and national resources in a partnership arrangement. Primary goals were to

- explore how we can connect the schools to the Internet in a **scalable** manner;
- document the model for use by other schools; and
- use the middle school as an educational networking testbed to determine
  - factors involved in connecting a school;
  - ways to help students, teachers and administrators use the resources effectively;
  - ways to train teachers to be system managers; and
  - steps for helping connected schools to become self-sufficient.

Success Factors

Major keys to the project's success were as follows:

- Significant, dedicated, continuous administrative support (*the principal*)
- Dedicated, qualified school computing staff that supported networking (*lab teachers*)
- Adequate, state-of-the-art hardware and software provided by the school system
- Facilities dedicated and supported for computer networking (*existing lab*)
- Technical support for start-up, network design, and training (*LANL staff*)

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Characteristics

Figure 1 is a schematic of the LAMS model networking project. Distinguishing characteristics of this model include the following catergorized features.

Technical Design:

- Central computer lab, with additional satellite workstations throughout the school
- Central, UNIX-based server accessed only by the school's system administrators
- Liberal use of public domain software
- Security plan

Strong, Coordinated School Approach

- Ongoing support by the school administration
- Dedicated and qualified school staff supporting computing and networking
- A financial plan and proposals for hardware and software acquisition
- Collaboration with parents knowledgeable in the relevant technologies
- Request for state-of-the-art hardware and network architecture
- Incentives for teachers to learn about and use computer networking resources

User Support

- Training program for lead teachers
- Training workshops for all school teaching and administrative staff
- Computer lab scheduling to allow usage opportunities for students and teachers
- Consulting support

Monitoring and Evaluation

- LANL monitored the effectiveness of the teacher training sessions and the school's overall use of the Internet. The evaluation took the form of direct observation, interviews with students and teachers, examination of curricular applications and output (projects that used Internet information), and questionnaires.

III. DESIGN AND IMPLMENTATION

Equipment And Connectivity

The LAMS computing environment is comprised primarily of Apple Macintosh (Mac) computers connected by an Apple LocalTalk network to several printers. Several models of the Macintosh exist within the LAMS environment, ranging from Classics to a Centris 610 with the most common model being the LCIII. We found that the tool, InterPoll, from Apple worked well to survey machine types, system versions, and printer software versions.

The main computer lab was divided into two networks because there were too many systems to be connected on a single LocalTalk network. Each network has a GatorBox that acts as a gateway for a PhoneNet link to the Ethernet. All systems were upgraded with MacTCP (version 2.0.2) to insure that system software would work with MacTCP (Macintosh Transmission Control Protocol).

Configuration of each Macintosh was tedious but straight forward. Each system needed a unique system name, a default username, and an IP (International Protocol) address. Specific parameters, such as the gateway and name server addresses for MacTCP, were set on a default version that was loaded on each system. Therefore, only those parameters unique to each system had to be entered manually.

In this particular situation, the local high school was already connected to the Internet; so we needed only to provide a connection from the middle school to the high school. This connection, a basic rate Integrated Service Data Network (ISDN) line, was provided by USWEST, the local phone carrier. LANL staff specified the ISDN line, hooked up the line to both LANs at the two schools, and performed troubleshooting of the ISDN line and the connections. The middle school ordered the ISDN line from USWEST and specified where the line was to be installed.

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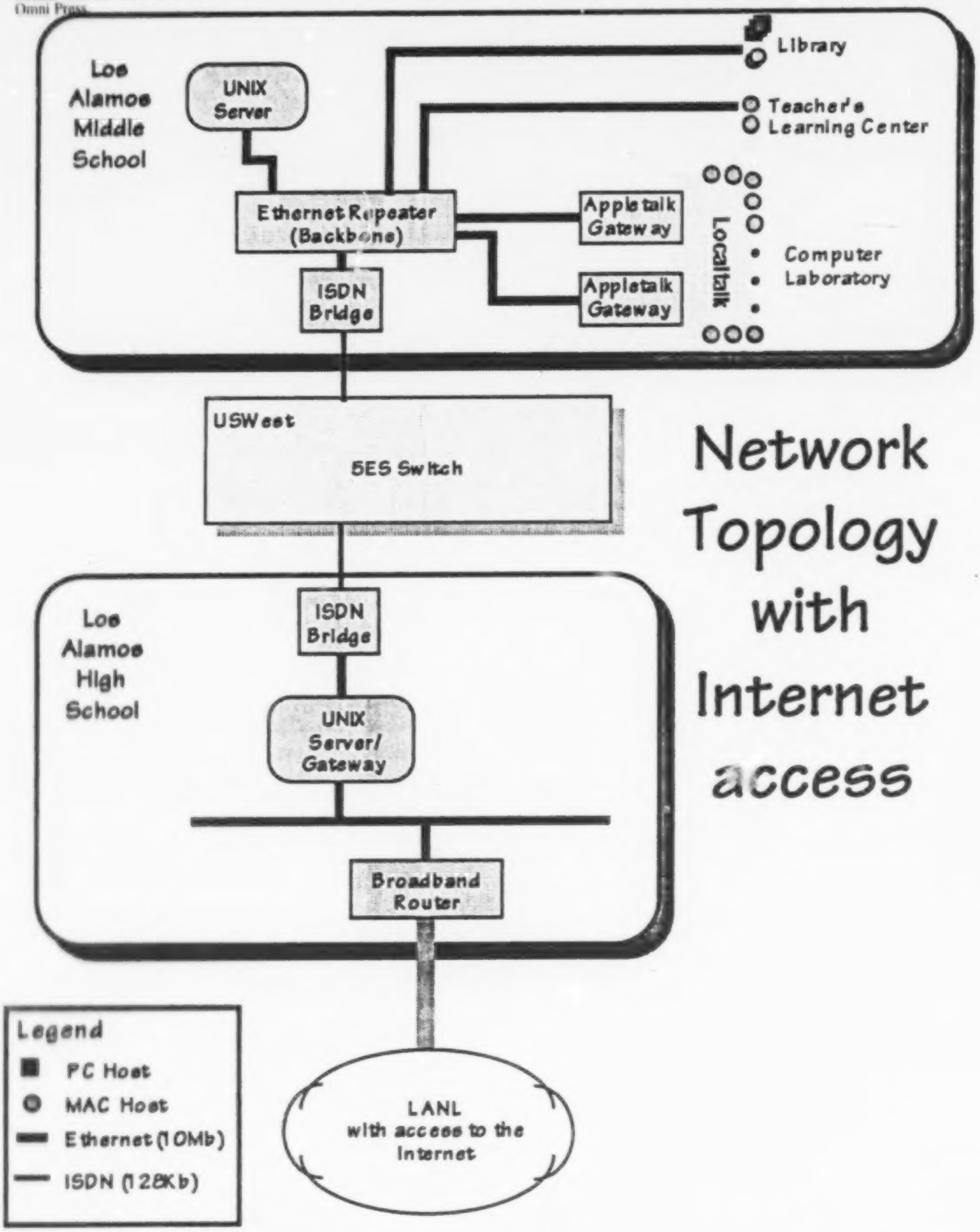
Los Alamos Middle School
UNIX Server
Library
Teacher's Learning Center
Ethernet Repeater (Backbone)
Appletalk Gateway
Appletalk Gateway
Localtalk
Computer Laboratory
ISDN Bridge
USWest
5ES Switch
Network Topology with Internet access
Los Alamos High School
ISDN Bridge
UNIX Server/ Gateway
Broadband Router
LANL with access to the Internet
Legend
PC Host
MAC Host
Ethernet (10Mb)
ISDN (128Kb)

Figure 1. Middle school network topology with Internet access.

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Software

An essential step was to determine the requisite software for the server and find software to support the goals of the project for the Macintosh clients. Most of the required software was freely available over the Internet. The project initially required software that would access Gopher servers, World Wide Web (WWW) servers, network news servers and also facilitate electronic mail (e-mail) connectivity. Some support software was also needed.

The next step was to install the requisite software on the server. Software servers set up on the UNIX-based workstation included: POP (Post Office Protocol); DNS (Domain Name Service); Gopher, enhanced anonymous FTP (File Transfer Protocol) service; and WWW.

Public domain and commercial software packages were selected, obtained, and installed. Public domain software obtained over the Internet to meet project goals included: TurboGopher, NCSA Mac Mosaic, NewsWatcher, and Eudora (with support utilities StuffIt Expander, JPEGview, Sparkle, Ulaw, UlawPlay, SimplePlayer, Image, DownLine, and NCSA/BYU Telnet).

Commercial packages purchased by the school were also installed and included: Apple MacTCP, Apple Quicktime, and VersaTerm Network Utilities

Other public domain software packages loaded for specific projects included: BinHex 4.0, Compact Pro, Digital Camera, InterNews, InterPoll, GradeBook, Kolor 2.0, MacWAIS, MoviePlayer, SndPlayer, Talk-2-me, Tidy it up, Ultra Recorder, and MacTCP Ping.

Issues and Problems

Equipment: The use of a UNIX-based server can be seen as both a strength and a weakness of this model. The strength is that it enables us to easily provide network services such as DNS, POP, and other servers using public domain software. The weakness is that UNIX and its administration are nontrivial to learn; therefore, nearby experts who are willing to assist on an ongoing basis at the beginning of the effort are essential. The robustness of the UNIX server and the proximity of experts at LANL made this a cost-effective testbed approach. As the technologies improve and the number of UNIX experts increases, this weakness will probably disappear.

The Macintosh is designed to be a "personal" computer; it assumes that only one person will be using the system. Specifying a "username" presented a problem because these systems were in a computer lab and would be used by many students and staff members. Therefore, we adopted the approach of specifying a generic user for each system; for example, a system named "Mac-12" had a corresponding username of "User-Mac-12." For most of the applications, having a generic username presented no problem. However, for e-mail, this created a major hurdle to overcome. Luckily the solution was simple. The e-mail software was not installed on any of the systems in the computer lab. Each user was given a diskette that contained Eudora, the e-mail utility, and a unique settings file that identified them as the user. With the diskette, users could retrieve and archive mail, and they could move freely between systems while preserving the privacy of their e-mail.

Software: Particular attention was paid to software versions. This was especially true of system software such as MacTCP. We were careful to use the latest version of software and ensure that it was compatible with the operating system on each Macintosh. Most systems were running version 7.1 of the MacOS; however, a few older machines were running earlier versions.

Furthermore, keeping the software base current with the latest release of each application is not trivial It is important that the systems users have a consistent software environment. New software must be introduced carefully to lessen the impact on these mostly novice users. We have yet to work out a standard procedure for the introduction of software upgrades.

System Clocks: Once systems are connected to one another in a LAN, synchronizing their internal clocks is important. As you move software from system to system in the network, having an accurate time associated with files is important so that you know which file is the newer version. We used VersaTerm Time Client as a utility to deal with this problem; it updates the system clocks across the network from a network time server.

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Communications Lines: We had major problems getting the ISDN line installed correctly. Most of the problems were delays; it took a long time to get the line installed. Once the line was installed, many phone calls were necessary to troubleshoot the line and the local carrier's switching equipment.

IV. TEACHER TRAINING AND INTERNET USE

Lead Teacher Training and Support

When it became apparent that the installation of the Internet connection and LAN was imminent, two lead teachers were trained as the system administrators. These lead teachers were to get a head start in learning how to access and effectively use Internet software and information. The lead teachers served as system administrators, learning to use UNIX on the server, and as Lab assistants during initial teacher training hands-on workshops. Now they are Internet teachers for classes of students and also provide individualized instruction and consulting for teachers, students, and staff.

Teaching and Administrative Staff Training Sessions

Two teacher training sessions were designed and held for *all* LAMS teachers and administration staff. In the first session, teachers learned to access information through Mosaic and Gopher servers and get net news using NewsWatcher. In the second session, they learned about e-mail using Eudora. In these sessions, the staff worked in pairs for one-hour periods listening to descriptions of tools and capabilities and then using the tools hands-on in the lab.

Evaluation results revealed that most of the teachers agreed that they wanted to learn more about computer networking and thought the resources, especially Gopher and Mosaic, were incredible. In the first session, teachers began to see the value of the network to their curricula; but they truely comprehended the Internet's (power, importance, significance) by the second session. Teachers stated that networking was valuable in their classrooms, lesson planning, and curricula in the following ways: doing research, sharing information with other schools across the nation and world, locating statistical data for debates and persuasive speeches, corresponding by e-mail , problem sharing/solving, finding interests of students, and locating career information/suggestions. Teacher's comments about the potential benefits of computer networking included: excellent research tool, expanding the walls of the media center, more resources, more options, limitless, too many to list, new method of instruction, and more efficient use of time.

Teacher Use of the Network

Teachers continue to use e-mail and the Internet for research and to share ideas. For specific research topics, teachers have searched the Internet by keyword. One social science teacher used 1990 census comparative data to gain current, accurate, information about Los Alamos fora student video project. Social science classes studying New Mexico have used the National Weather information and satellite images for ongoing reports on New Mexico weather. Another teacher asked for lessons or information on civil rights and/or prejudice to use in conjunction with a unit on Dr. Martin Luther King. He was amazed by the variety and excellence of the lesson plans that he found on the Internet. These are only a few examples; the list grows daily. It is very encouraging to teachers to be able to find something and say, "This is exactly what I need!"

The teachers also use the network to get the "latest breaking news" on topics for use in their classrooms. For example, the day after the recent earthquake in Los Angeles, a teacher used the Internet to get the latest breaking news as well as general information about earthquakes to use with classes that day.

Important Note: These are primarily novice users. The initial teachers' workshops were held only three months before the writing of this paper.

V. STUDENT TRAINING AND INTERNET USE

Shortly after the first teacher training workshop, a group of 15 students from the 8th grade Gifted and Talented Education Program (GATE) was introduced to the network. Each student was given an e-mail address, password, and a Eudora disk. The lead teachers then taught the students how to send e-mail. They began by sending mail to each other and then to friends, teachers, and family members, as well as to peers outside the school network.

After the initial session, students were invited to use the computers during open periods, and they took full advantage of this invitation. During sessions, it was not unusual to hear a student exclaim, "Hey, I got a message from my dad!" or "I have to leave a message for my mom to tell her that I'm going to Susie's house after school."

News at the school travels about as fast as e-mail on the Internet; so right after our first session with students,we had about ten students approach the lead teachers for e-mail addresses and access to the Internet. The lead teachers decided to hold another training session for the original 15 GATE students to introduce them to Gopher and Mosaic before starting with another group. In that session, the students quickly found shareware software, census information, and satellite images using Gopher. They also discovered Dr. Fun and museum resources with Mosaic.

Several new introductory sessions have now been held for other groups of students. Students can sign up for an Internet class and get addresses during a "Stretch" period," (two-hour periods, offered once a week, when students can choose special activities). The first to sign up get in — the sign-up list for the "Internet Stretch" is always full!

We also discovered Listserv information and suspected it would be of interest to the students; we were right — they took off. One particularly valuable Listserv was KIDLINK. This links kids, ages 10 to 15, through e-mail to other kids around the world. By this time, more students had asked for access to the Internet and e-mail addresses. We have students sign an agreement about proper use of e-mail along with their application for an e-mail account.

We have received mail from kids in many countries including Norway, Germany, and Russia. As David Hollman, a member of the first Global Classroom Youth Congress stated, "There's no way I could have opened a textbook and gotten the same information I obtained from online dialogue with peers in Israel, Russia and China." (Itzkan, 1994).

After approximately three months 69 students have attended e-mail/Internet classes and are using e-mail and Internet resources — with classes and individually. In addition to these voluntary sessions, classroom teachers, assisted by the lead teachers, bring entire classes to the computer lab to use the Internet for specific purposes and activities.

VI. TECHNICAL AND CONSULTING SUPPORT

LANL staff provided technical guidance and support for hardware connectivity, network growth, and installation and use of network/user software. They helped the middle school staff network their computing facility to the outside world with Internet and e-mail, and now they continue to provide consulting support. When a problem was unrelated to the network connection itself, e-mail emerged as the most effective method of consulting.

VII. SUMMARY

Clearly, this model of school networking is a stage in an evolutionary process. Lessons learned are numerous and, as shown in the problems section above, the installation of the network in an educational setting with a pre-existing computer lab had both advantages and disadvantages. However, now that everything is up and running, we find that keeping up with the usage and application needs of motivated teachers and students is the primary challenge.

As this paper goes to press, the model illustrated here is being used to design an educational networking system in another school district. Lessons learned here, especially the keys to success, are being directly applied to this new project. The model will be refined as new testbeds yield new insights and information.

Installation of the technology, however, is just the first step in experiencing the Internet in an educational setting. As collaborative learning becomes a major form of instruction, new and yet unknown Internet learning experiences will occur; thus new educational uses for the Internet will emerge. We therefore see our next step to be continued evaluation and refinement of this model as we wait, watch, document, and continue to learn.

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Van Staden, J.C. & Carr, B.A. (1994). Microsoft windows and visual basic as authoring platform for computer-based instruction. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 69-75). Nashville, Tennessee: Omni Press.

Microsoft Windows and Visual Basic as Authoring Platform for Computer-based Instruction

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Abstract: A study of available authoring packages was made. It was realised that object oriented techniques and a grapic user interface (GUI) such as Microsoft Windows would have to be used. The reasons for selecting MS Visual Basic as the authoring language is presented. In its standard form VB does not contain response analysis algorithms and the sophisticated text handling needed for CBI. However, it's open structure allows custom controls and DLL's to be incorporated. The specifications of these utilities and their programming in C/C++ will be discussed. The aim is to provide an efficient authoring tool for the lesson designer and programmer. The relatively low price of VB and the value of royalty free distribution of courseware written in VB is pointed out.

Introduction

> *About two years ago I saw Microsoft Visual Basic for the first time and decided that I was looking at the future of computer programming --- period*
>
> ...
>
> *Suddenly, here was a tool that allowed me to write applications in hours that literally used to take two weeks. What's more, it was powerful and extensible enough for use in serious professional applications.*

Dan Appleman. 1993.Visual Basic Programmer's guide to the Windows API.
(PC Magazine, ZD Press)

This quote from Dan Appleman's book portrays the same excitement that we experienced on our first exposure to Microsoft's new programming language for Windows, Visual Basic. We, however, were looking at VB with completely different eyes. We saw the potential of turning VB into a powerful authoring tool for producing sophisticated CBE courseware efficiently and fast.

Why were we looking at authoring systems? The Gold Fields Computer Centre for Education at the University of Pretoria has a dual network for delivering courseware to eighty student terminals. The first one is the mainframe-based CDCNET on which CYBIS (successor of PLATO) is run. The second network is an up-to-date ethernet/Novell LAN driven by a 486 file server. The same IBM compatible PC's serve as terminals for both systems. For a number of years CYBIS was the backbone of activities at the centre. High maintenance costs and an increasingly unreliable CYBER have precipitated the decision to phase out the mainframe while developing software for the LAN. Thus our interest in finding a suitable authoring package. We wanted high productivity with state-of-the-art quality and sophistication. At the same time we want to promote the widespread and large scale use of computer assisted learning in our region. We decided that a graphics user interface (GUI) and object oriented techniques were desirable, with Microsoft Windows being the obvious choice. The Windows packages we investigated were either prohibitively expensive, or not strong enough in

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certain essential areas such as response analysis, or plagued with annoying royalty and licensing restrictions. Visual Basic, being a programming language not specifically designed for the production of courseware, was also lacking in two important ways: response analysis and a symbol editor for scientific applications. However, it had none of the other disadvantages. It's visual interface was very easy to use and it's open structure was particularly attractive. Apart from a full set of Basic language functions, most of the functions from the Windows API can be incorporated. In addition, the full power of the C/C++ language can be used to program add-on procedures, functions and custom controls. We realised that with some late night programming we could fill in the gaps to turn VB into a system that would meet our requirements handsomely.

To learn is to create

The ultimate objective of any computer-based instruction is to create an effective and meaningful learning environment. Educationists have been studying the learning process for centuries. In our view one of the key factors in effective learning is creativity. Creativity is an indispensable part of learning. Furthermore, creativity and learning are very personal concepts. Nobody can learn something on someone else's behalf. Learning is the personal creation of knowledge and teaching is facilitating this creative process. In computer-based instruction creativity (learning) is promoted by establishing continuous interaction with the learner at the terminal. The normal way to do this is to pose a question to which the learner must create an answer. The learner's attempt must then be analysed and judged, not only for correctness, but more importantly in the case of a wrong response, for the flaw in the reasoning. Meaningful feedback should then be given to the learner as well as the opportunity to try again. The purpose of these guidance questions is not to test the knowledge of the learner, but rather to focus the mind and to guide him or her to gain new knowledge. Often a wrong response provides the perfect opportunity to teach. The full facility of the computer system should be available when compiling the feedback. The feedback could be another question to probe deeper and perhaps find the student's misconception. It could contain all the multimedia components and could branch to another section of the lesson or even to a different lesson. Programming these feedback loops can be very tedious if the authoring package is not geared to help the lesson designer. It is heart-breaking to see how often the feedback, where it matters most, is treated superficially, and how often the correct answer is simply given after one or two wrong attempts, before the learner had a chance to discover (create) the knowledge. Some authoring systems allow only a correct/incorrect feedback to a student's response, which is hopelessly inadequate.

Another consequence of the reasoning given above is that we try to avoid multiple choice type questions wherever practically possible. Pick & choose type interaction leaves little scope for creativity. As a result learning is not very effective and retention is low. True/false type questions are even worse. Many of the features of the authoring shell which is described in the following paragraphs are intended to simplify the proper implementation of the response analysis - feedback loop.

The Visual Basic Scene

Figure 1 is a screen dump of the VB design time screen. It is a 800X600 SVGA screen, where the central form is a 640x480 area which will become the student screen at run time. (On the illustration the image has been reduced to a practical size for printing). It is not the purpose of this paper to explain all the standard features of VB. A description of these features can be found in the manuals, and many people are familiar with VB anyway. We would, however like to point out the features which are of particular importance from the lesson designer's point of view.

On the left hand side of the screen the control box is shown. It contains the standard controls as well as any number of custom controls which could be added when needed. The two last controls, the foot print and ANS, are custom controls created by us. They form the core of our VB authoring system and will be discussed in some detail. Hundreds of other custom controls are continuously released by independent developers world wide. Apart from the possibility of creating one's own, the lesson designer has an incredibly rich selection of controls at his disposal.

Controls are dragged onto the form where they become objects. Each object has a number of pre-defined properties. The values of these properties can be changed on the properties window. Basic language code can be attached to each object. This code is activated by certain events such as mouse button clicks and key presses. A lesson or application would consist of a number of forms, each containing a variety of objects. These

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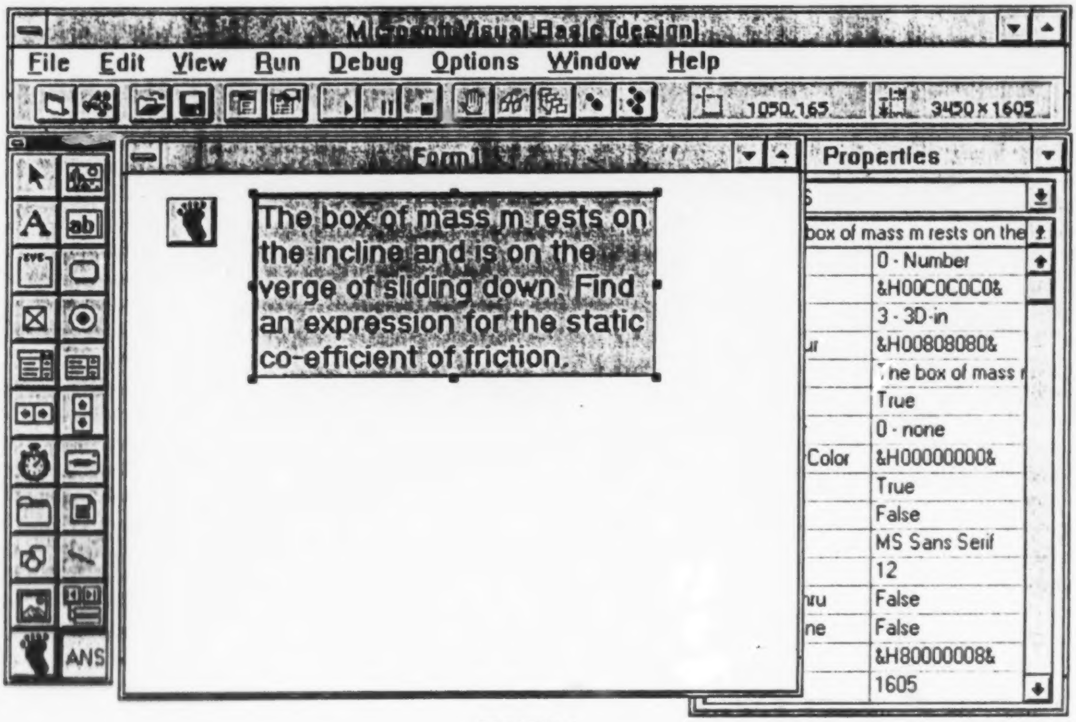

The box of mass m rests on the incline and is on the verge of sliding down. Find an expression for the static co-efficient of friction.

box of mass m rests on the

	0 - Number
	&H00C0C0C0&
	3 - 3D-in
ur	&H00808080&
	The box of mass
	True
	0 - none
Color	&H00000000&
	True
	False
	MS Sans Serif
	12
hru	False
ne	False
	&H80000008&
	1605

FIGURE 1

objects can be independent or linked in many different ways. The object oriented nature of VB programs gives great freedom to the lesson designer to individualise navigation through a lesson, with minimum code and very little programming effort. Educationally this is an important feature and in harmony with our demand of maximum creativity.

Figure 2 shows the properties window of our ANS control. Many of the properties are the same as for the standard VB text box and deal with border styles, colours and fonts. The additional ones, however, give us the authoring features. If the *Question* property is FALSE the object is a text box with enhanced border options, but some other properties disabled.

If the *Question* property is switched to TRUE, the text box is used to phrase a question. The *AnsType* property is then used to classify the type of response expected. This information is used to select the appropriate response analysis algorithm.

At present the following types of responses are foreseen:

0. Number: A numeric response with awareness of the correct number of significant figures, but without units.
1. NumberUnit: The same as Number but with units. Automatic adjustment for different correct units is incorporated.
2. Text: Judged for key words with spelling tolerance.
3. MathExpression: Symbolic mathematical expression. Automatic allowance for different correct forms of the expression.
4. MathEqaution: Two mathematical expressions separated by an equal sign. Alternative correct grouping of symbols allowed.
5. ChemExpression: Chemical expression. Correct alternatives allowed.
6. ChemEquation: Two chemical expressions separated by an equal sign or arrow.
7. Diagram: A diagram created by dragging and dropping pieces.
8. MultipleChoice: One or more correct alternatives and a number of distractors.
9. Match: Matching of two columns of information.

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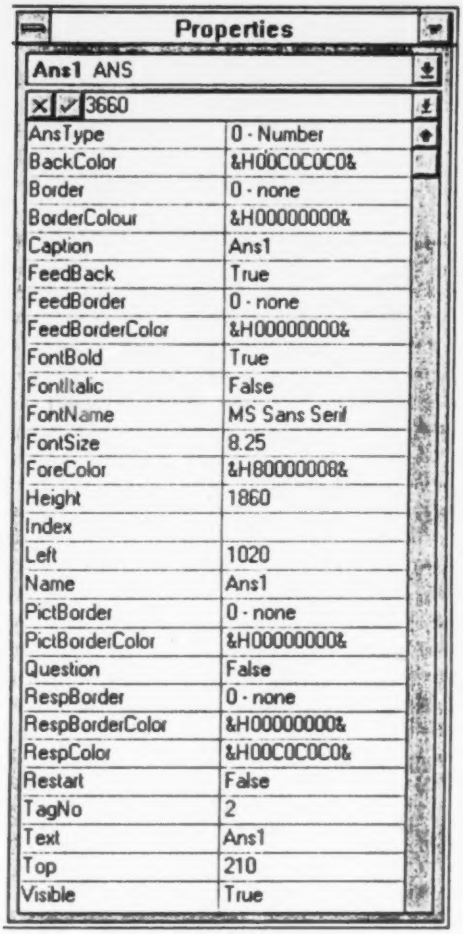
Not all of these types will be implemented mediately, but the response analysis algorithm library will be ontinuously developed and enhanced. New types will also be added to the list when needed. One challenge we intend to take up in future is to provide response analysis for music notation.

The*Feedback* property can be set to FALSE. This will be the case when the question is part of a test where the response is judged and graded, but no feedback given. Online tests and examinations could be set very easily and quickly.

The *Restart* property sets a restart flag. Each ANS object will also be a restart point in the lesson when *Restart* is set to TRUE. The learner will return to the most recent ANS object with a TRUE *Restart* property when he restarts a lesson that was interrupted.

The *TagNo* property is an identification tag which is automatically allocated to each ANS object by the system when it is created. This tag is used by the FOOTPRINT control to keep track of the ANS objects throughout the lesson. If the designer does a right button click on the foot print a list of all the existing ANS objects is displayed in a pop-up window. The list indicates the settings of the *Question* and *Restart* properties as well as the first few word of the text in the ANS box. This feature is intended to help the designer to have an overview of the lesson and to find the reference for branching to any ANS object quickly. The FOOTPRINT only appears on the design screen and has no impact on the screen at run time.



Ans1 ANS

3660

AnsType	0 - Number
BackColor	&H00C0C0C0&
Border	0 - none
BorderColour	&H00000000&
Caption	Ans1
FeedBack	True
FeedBorder	0 - none
FeedBorderColor	&H00000000&
FontBold	True
FontItalic	False
FontName	MS Sans Serif
FontSize	8.25
ForeColor	&H80000008&
Height	1860
Index	
Left	1020
Name	Ans1
PictBorder	0 - none
PictBorderColor	&H00000000&
Question	False
RespBorder	0 - none
RespBorderColor	&H00000000&
RespColor	&H00C0C0C0&
Restart	False
TagNo	2
Text	Ans1
Top	210
Visible	True

FIGURE 2

The Response Dialogue Window

Each question normally has a correct response (or a few alternative correct ones),but there are many ways to answer a question incorrectly. It is impossible to treat all these wrong options in a program of practical proportions. The experienced educator who knows his subject well, also knows which wrong answers occur frequently, and what flaws in the reasoning cause them. It is therefore possible to anticipate a number of wrong answers and to provide feedback to correct them. We decided, as a starting point, to allow for ten different Responses to each question, one correct one and nine wrong ones. The number of ten is arbitrary and only one constant in the source code needs to be changed should a different number of responses be required. (Of course it is not necessary to use all ten for every question). To strengthen the feedback in accordance with the importance we attach to it, we make provision for an optional second feedback to every

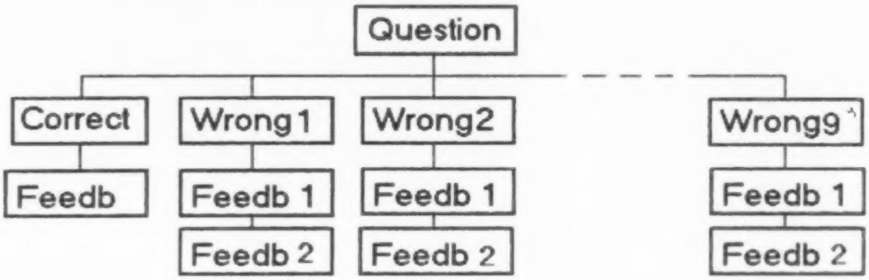


FIGURE 3

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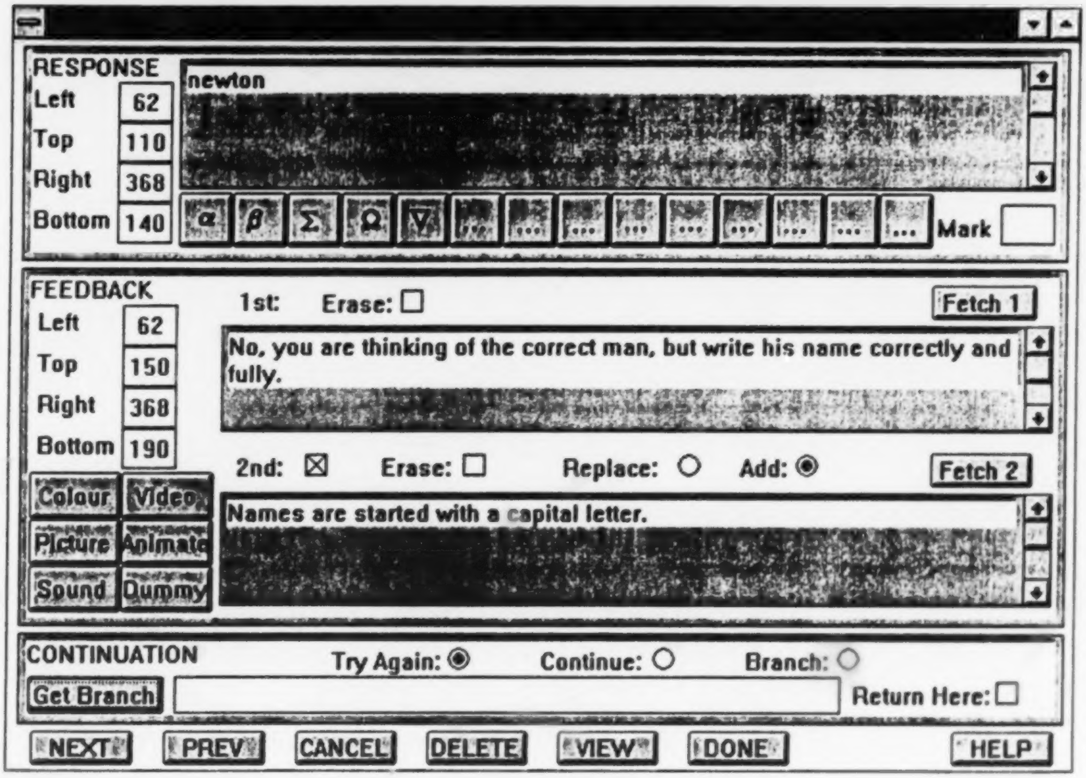

RESPONSE
Left 62
Top 110
Right 368
Bottom 140
newton
Mark

FEEDBACK
Left 62
Top 150
Right 368
Bottom 190
1st: Erase: ☐
No, you are thinking of the correct man, but write his name correctly and fully.
2nd: ☒ Erase: ☐ Replace: ○ Add: ●
Names are started with a capital letter.

CONTINUATION
Try Again: ● Continue: ○ Branch: ○
Return Here: ☐

FIGURE 4

wrong response. The diagram in Figure 3 shows this schematically. When the *Question* property is TRUE a right button click on the ANS object activates the response dialogue pop-up window as shown in Figure 4. This feature is a design facility only and is not active at run time. The designer can click on the NEXT and PREV buttons to page through the ten responses. Apart from the buttons at the bottom the dialogue window is divided into three sections.

The top section contains the anticipated RESPONSE and information associated with it. The co-ordinates of the rectangle where the response will be entered is displayed on the right. The rectangle is positioned visually on the screen, but the designer can override this by editing the numbers, especially when small changes are needed. The buttons below the text box are used for special characters by the scientific editor (see par. 5). If the question is to be graded, a mark can be entered into the "Mark" box.

The second section contains the FEEDBACK. When the *Feedback* property is set to FALSE this part of the window does not appear. Two text boxes are provided for the first and optional second feedbacks. Normally the feedback stays on the screen when the student tries again. If the "Erase" buttons are switched to "on" the feedback is erased. If the same wrong response is given a second time the second feedback is used. It can either replace the first feedback or it can be appended to the first feedback according to the setting of the "Replace" and "Add" buttons. The response and feedback data are stored as invisible properties of the ANS object. Sometimes the feedback will be the same as the feedback to a previous question. In that case the designer can fetch such feedback by using the "Fetch" buttons. This saves memory and retyping of previously entered text.

As stated earlier we feel that the full facility of the system should be available to be used in the feedback to the student. The buttons in the lower left corner are meant to add different colours, a bitmap and multimedia features to the feedback. These things are of course standard features of Windows and VB, but it should be understood that these buttons are used to attach a bitmap, let's say, to a feedback to a specific response to a specific question.

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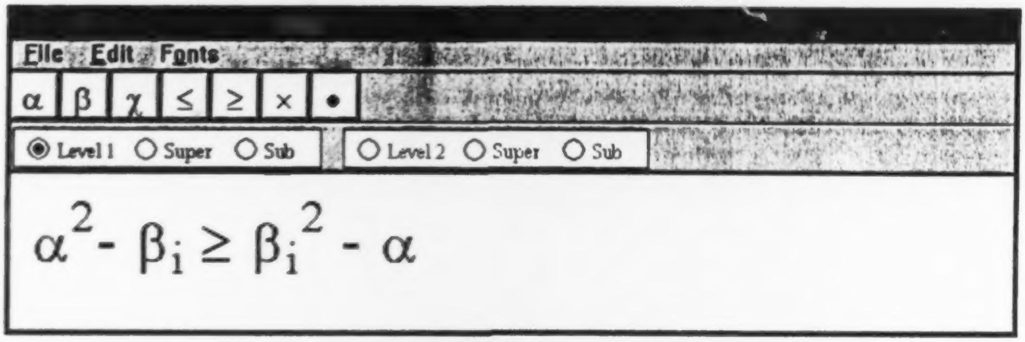
The third section controls the CONTINUATION after the question has been answered. The student will either try again or continue to the next object in the lesson. Sometimes the designer might feel that ordinary feedback is not enough to resolve the learner's problem and that he (the learner) should work through another section of the lesson before his next attempt at answering the question. The branch button activates this option. By clicking the "Get Branch" button the FOOTPRINT list window is displayed. The designer then selects an object from the list and enters the reference into the box by clicking "GetBranch" again. The "Return Here" button determines whether the learner returns to this point in the lesson after the branch. The branching facility is particularly useful and important when a secondary question is needed as feedback.

The Scientific Editor

As mentioned earlier, very little emphasis is placed on typed answers in current CBI authoring packages. Of those that do accept typed answers, even less thought is given to an author wishing to have the student input an answer using mathematical symbols and/or superscripts and subscripts. The most obvious reason for this is firstly, the difficulty in analysing the response, and secondly, the student normally has to learn a complicated sequence of keystrokes to produce one of these characters. We have found that this, more than anything else, frustrates the student, and as such detracts him from the learning process. We decided that all aspects of the input mechanism should be completely visible to the student, so that if he can operate the mouse and the keyboard, he has all the tools required to answer a question. Special character selection is then as simple as using the mouse to choose a character from the "softkeys" such as those shown in the diagram below.

The diagram below is from the lesson developer's editor, which is a superset of the student's editor. The author has the extra features shown on the menu bar which allows him normal editing facilities and the ability to set special characters on buttons which the student may or may not require. Of course if this is to be a "text box", then all that will appear in the window on the student's screen will be the "text". The scientific editor has been written in C++ to make full use of dynamically allocated objects to store items such as the buttons required to answer a question, as well as the answer itself. The parser then uses this same information in analysing the answer. The editor and the parser are in a standalone DLL, and have a series of C functions to allow other windows systems to communicate with them.



$$\alpha^2 - \beta_i \geq \beta_i^2 - \alpha$$

FIGURE 5

The Manager

VB3.0 also features a database control with a native MS ACCESS format. However, it can connect to several popular database formats such as dBase and Novell's Btrieve. Because it is internal to VB, it is very easy to use it as the database to control the Lesson Delivery System (LDS). This database needs to contain, for each student, details of the current curriculum, the current lesson from the curriculum, restart markers and statistics such as lesson usage. The LDS can then load the required lesson, and update the database continuously on receiving information from the lesson. The manager is the final phase of this project.

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Conclusion

Although all the features mentioned in this paper are not implemented yet, we feel that Visual Basic and our authoring custom controls will soon provide us with the authoring system we need. As mentioned earlier an important advantage of using VB as an authoring package is cost effectiveness. The standard package costs a fraction of the price of established authoring systems. Furthermore, all compiled programs written in VB can be distributed free of any royalties and licensing restrictions.

Nesbit, J. C. (1994). Prerequisite Coherence in Instructional Presentations . In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 76-83). Nashville, Tennessee: Omni Press.

Prerequisite Coherence in Instructional Presentations

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Abstract: Although widely accepted as fundamental to the instructional design process, learning hierarchies (Gagne, Briggs & Wager, 1988) do not fully specify the presentation sequence of a set of instructional objectives. Memory load theory (Nesbit & Hunka, 1987) more thoroughly exploits the structure of learning hierarchies by proposing that the most effective instructional sequences minimize the distance over which prerequisite links are extended. The present study investigates the extent to which textbook authors order sections within chapters to conform to this principle. Twelve chapters from math and science textbooks were analyzed to obtain underlying learning hierarchies. The hierarchies were compared with the actual sequences chosen by the textbook authors. There was strong evidence that authors preferred sequences characterized by high prerequisite coherence. It appears that authors do not consciously strive to minimize memory load, an optimization problem that is generally intractable, but rather follow a depth-first *satisficing* strategy. Implications for the design of computer-based instruction are briefly discussed.

The sequencing of instructional presentations is a problem of long-standing interest to instructional psychologists, and one for which a variety of prescriptive theories have been proposed (Posner & Strike, 1976; Patten, Chao & Reigeluth, 1986). Prominent among these is the highly influential formulation originated by Gagne (Gagne & Paradise, 1961; Gagne, 1962) and stated most recently in Principles of Instructional Design (Gagne, Briggs & Wager, 1988). Though rooted in the transfer of learning psychology of the 1950s, Gagne's theory has proven remarkably portable across the collegial boundaries that separate specialists in training, instructional technology, education, and psychology. It has remained a mainstay in handbooks and textbooks dealing with instructional design (e.g., Jonassen, Hannum & Tessmer, 1989), yet has been taken up, often in variant forms, by researchers applying cognitive science to the development of intelligent tutoring systems (Lesgold, 1988).

To design instruction for intellectual skills, or procedural knowledge, Gagne advocates a form of task analysis which recursively decomposes a goal skill into sub-skills linked by the prerequisite relation. The resulting structure, called a learning hierarchy, has three vital functions in the planning and execution of instruction: (1) it defines a partitioning of the content into discrete instructional objectives, (2) it specifies restrictions on the order in which instructional units covering the objectives may be presented to the learner, and (3) when learning fails it points to prior objectives that are candidates for review.

The size and content of each objective in a learning hierarchy is primarily determined by the following criterion: If all prerequisites are in place and minimal instruction is supplied, the objective should be sufficiently simple such that the learner will be able to immediately achieve a successful, though not necessarily masterful, performance of the skill addressed by the objective. In some domains a hierarchical analysis can enable the supplied instruction to be reduced to only a series of guiding questions or problems posed to the learner. The aim of a hierarchical analysis, then, is that instruction be so formed and ordered that the learner be ready to rapidly assimilate the target skill when supplied with minimal new information. Because this

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sort of analysis defines each objective under the assumption that all its prerequisites will be available to the learner, it is crucially important that when the moment for transfer arrives prerequisite knowledge not only have been attained but also retained.

Memory for Prerequisites

For facilitating access to attained prerequisite knowledge, there are three mutually compatible types of strategies available to an instructional system.

(1) At time t^1, when prerequisite knowledge is acquired, deploy instruction which ensures a durable and accessible memory trace: Provide practice, mnemonics, schema induction, and so on.

(2) At time t^2, the moment of transfer, deploy instruction which stimulates effective retrieval of prerequisites: Provide cues to guide memory search, activation of relevant schemata, analogies that illustrate the relation between prerequisite and current objectives, and so on.

(3) Minimize the interval between t^1 and t^2.

The first two strategies are explicitly recognized by Gagne:

> To be most effective for new learning, prerequisite skills must be thoroughly learned, that is, learned to *mastery*. Presumably, this degree of learning makes the prerequisite skills easier to recall and, therefore, more readily accessible for new learning. Another condition that affects the ease of retrieval is the number of cues available to the memory search process. Aids to memory search are provided by the cues of a schema. Accordingly, embedding the prerequisite skill (or skills) within the organized framework of a schema may be expected to have a beneficial effect on instruction. (Gagne, Briggs & Wager, 1988, p. 109-110)

But there are costs accompanying strategies that attempt to strengthen encoding or stimulate recall. Instruction on already comprehended knowledge takes additional time, and, especially if in the form of repetitive practice, can claim a toll on learner motivation. Moreover, there are instances where heavy mastery of part of a skill can interfere with later acquisition of the whole skill (Singley & Anderson, 1989, p. 114), as demonstrated in famous early studies on the Einstellung effect (Luchins, 1942).

Processing of retrieval cues must also be counted as a cost in cases where the prerequisite knowledge is already activated. Parallels can be drawn with the use of anaphoric reference in discourse: The clearest constructions delete explicit cues to information that is already established in the working memory of the listener. Similarly, in designing instruction, the use of elaborate prerequisite retrieval cues should be restricted to only those transfer points at which they are really needed.

Although largely neglected in the literature on learning hierarchies, the third and most passive of the three strategies has the advantage of requiring no additional instruction; and thus offers the greatest leverage against the tyranny of the total time law. If minimization of the prerequisite retention interval is given priority, then the two strategies which more actively promote access to prerequisites can be deployed as required.

There is evidence that the prescription to minimize prerequisite retention intervals is not simply an unarticulated assumption of learning hierarchy theory. While expressing a concern for retention of prerequisite knowledge, Lesgold (1988) could find no compelling reason to prefer depth-first traversal of the hierarchy over breadth-first traversal, concluding that "there may be individual differences in aptitude or preference for these two approaches". From memory load theory we can arrive at the contrasting position that a depth-first traversal is more effective for all learners because it generates shorter retention intervals.

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Prerequisite Coherence

Factorial explosion ensures that a set of only a dozen instructional objectives has many millions of possible orderings. To specify a learning hierarchy is to remove from consideration a large fraction of these sequences; yet a typical hierarchy can leave millions of sequences as valid possibilities for presentation to the learner. Memory load theory begins with the question: Can all sequences in such a large set be equally effective?

Nesbit and Hunka (1987) advanced the view that instruction is most effective when objectives are presented in sequences minimizing the interval over which prerequisite links are stretched. Here it is further argued that teachers, instructors and authors have an untutored tendency, when informed of the prerequisite relations among objectives, to choose sequences exhibiting this sort of coherence.

For the three hierarchies shown in Figure 1, prerequisite coherence can be illustrated as a property of those sequences which contain the segments VW and XY. For example, the sequence UVWXY is a coherent traversal of hierarchy 1.

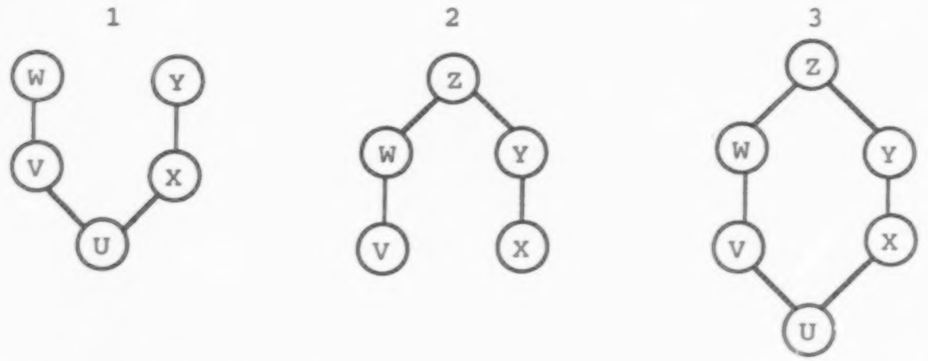

Figure 1. Three hypothetical learning hierarchies.

A simple way to quantitatively capture the memory load imposed by a sequence of objectives is to first assign a duration (i.e., an estimated learning time) to each objective, then sum the durations over which each link is stretched, and sum over all links. Figure 2 shows that, if a duration of 1 time unit is assigned to all objectives, the coherent sequence UVWXY for hierarchy 1 would evaluate to a summed duration of 2 time units, while the less coherent sequence UVXWY would evaluate to 3 time units. To allow comparisons across hierarchies, the summed duration for a sequence is normalized by obtaining its reverse-order percentile rank among the population of sequences permitted by its hierarchy. A sequence uniquely possessing the least summed duration of all sequences permitted by a hierarchy would thus have a prerequisite coherence approximating 100, while the coherence of a sequence uniquely possessing the greatest summed duration would evaluate to 0.

The two examples in Figure 2 highlight major facets of the prerequisite coherence concept. The coherent sequence (UVWXY) results from a depth-first traversal of the hierarchy, while the incoherent sequence (UVXWY) results from a breadth-first traversal. More generally, depth-first traversal does not guarantee maximum coherence but does seem to work as a serviceable heuristic. As further demonstrated by Figure 2, breadth-first traversal tends to uniformly distribute retention intervals over prerequisite links, while depth-first traversal tends to distribute unevenly by allocating most of the summed retention duration to a small subset of the links. Again, depth-first traversal should be preferred because (1) it allows better prediction of prerequisite knowledge likely to be forgotten and (2) due to the non-linearity of forgetting, it imposes a lower actual memory load for the same summed duration. For the coherent sequence UVWXY we can readily predict that the prerequisite link from U to X is the most likely to need additional instructional support, perhaps in the form of reviewing or cueing U. At the same time, the non-linearity of forgetting curves tells us that dividing a retention interval between two items results in greater total information loss than allocating the entire interval to a single item.

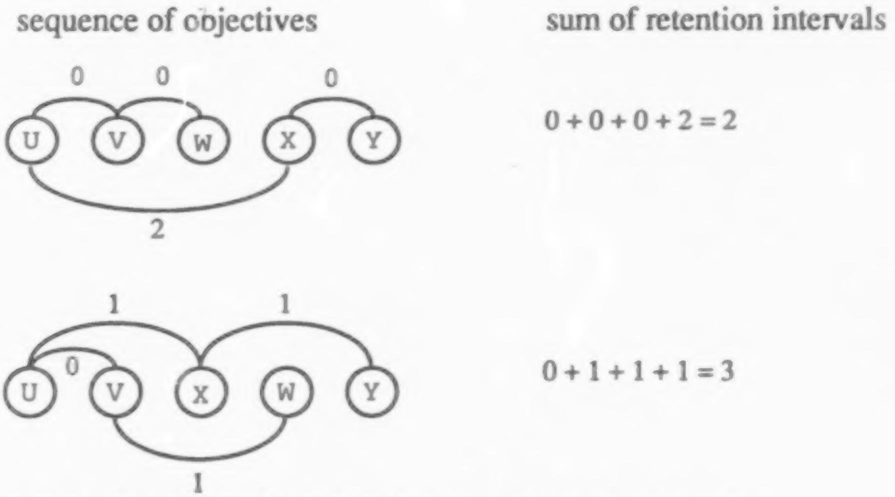

Figure 2. Estimating memory load effects by summing retention intervals.

To this point in the presentation, a simple definition of prerequisite coherence based on summation of retention intervals has been elaborated. A relative measure of coherence has been obtained by converting a summed duration into a percentile, such that the most coherent sequence for a hierarchy produces a coherence measure of 100. But without data we cannot be assured that this definition gives the most accurate measure of coherence. For the time being we need to work with a set of measures that can be compared and tested as predictors of learner performance and instructor preference. Theory-based variations on the core definition constitute an extended family of coherence measures, with each member representing a trade-off between definitional simplicity and theoretical validity. For instance, a power function of the retention interval can be introduced to better account for the fact that retention falls off non-linearly with time. Note that a linear coherence measure will not distinguish between depth-first and breadth-first traversals of hierarchy 3 of Figure 1, but that introducing a more natural non-linear function of the retention interval, such as square root, will result in a higher coherence rating for depth-first traversals. Another variation used here follows the principle that the retention interval should be calculated from the most recently attained objective having the prerequisite as a component skill, rather than from the prerequisite itself. Which variations best serve the instructional designer is a question to be addressed by empirical work.

For the purposes of the present study, a series of four increasingly refined prerequisite coherence measures were constructed: $D^{(1)}$, $D^{(2)}$, $D^{(3)}$, $D^{(4)}$. In order to define these measures, a few symbols and terms are now introduced. A learning hierarchy, and every sequence generated from it, contains m links or arcs, each connecting a prerequisite to a target objective. Each arc i of a sequence stretches across q_i objectives which intervene between its prerequisite and target objectives. Each arc of a sequence also has a single sufficient prior objective, which is the last (rightmost) objective before (left of) the target objective that either has the prerequisite as a component skill or is itself the prerequisite. For example, in the sequence UVWXYZ from hierarchy 3 of Figure 1, X has U as a prerequisite and W as a sufficient prior objective. Four estimates of memory load effects are now defined:

$d^{(1)} = \sum_{i=1}^{m} q_i$	A count of intervening objectives over which prerequisites must be retained.
$d^{(2)} = \sum_{i=1}^{m} \sum_{j=1}^{q_i} t_{ij}$	A sum of retention intervals over which prerequisites must be retained; t_{ij} is the estimated learning time of the jth objective intervening between the prerequisite and target objectives of the ith arc.
$d^{(3)} = \sum_{i=1}^{m} \sqrt{\sum_{j=1}^{q_i} t_{ij}}$	A sum of memory loads estimated as a non-linear function of retention interval.
$d^{(4)} = \sum_{i=1}^{m} \sqrt{\sum_{j=1}^{q_i} s_{ij}}$	A sum of memory loads estimated from sufficient prior objectives; s_{ij} is the estimated learning time of the jth objective intervening between the sufficient prior objective and target objective of the ith arc.

Each prerequisite coherence measure D is then a reverse-order percentile indicating the position of the target sequence in a distribution of estimated memory load effects d of all sequences generated from the same hierarchy.

The purpose of this study is to test the hypothesis that instructional texts show prerequisite coherence. Evidence for or against coherence in texts does not constitute a direct rejection or acceptance of the more central claim that prerequisite coherence facilitates learning; but it would contribute to or detract from the construct validity of memory load theory. If instructional design for computer-based instruction is construed as an enterprise of automating and systematizing the processes by which instructors arrange conditions for learning, then the finding that texts exhibit high prerequisite coherence would reveal a useful criterion for automated design. A separate experiment testing the central claim that prerequisite coherence actually facilitates learning is now nearing completion.

Method

Textbook chapters were analyzed to obtain underlying learning hierarchies. With these hierarchies in hand, prerequisite coherence values were calculated for the actual sequences used by the textbook authors.

As a preliminary step to this procedure it was necessary to develop operational definitions for the concepts of instructional objective, sequence, prerequisite, and learning time that play major roles in the construct of prerequisite coherence. It was decided to let a textbook chapter represent a single sequence of objectives, and to let chapter sections as denoted by the textbook author stand for instructional objectives. A chapter section was only considered to be a prerequisite of a later section if understanding or mastery of the later one clearly required understanding or mastery of the earlier one. Reference to terminology introduced earlier did not alone constitute a prerequisite relation if the terminology could have been briefly defined in the later section. Learning time for a chapter section was estimated by a count of sentences — the large sample of text forbade use of more precise estimates obtainable by propositional analysis.

Twelve chapters from mathematics and science textbooks were selected. In comparison with other academic subjects such as literature, prerequisite relations are more readily perceptible in mathematics and science because they include a larger proportion of procedural knowledge. Other selection criteria were:

- The hierarchy derived from the chapter should provide a sufficient basis to test a preference for prerequisite coherence. Occasionally hierarchies were found which completely determined the presentation sequence. In a few other cases, all possible traversals of the hierarchy generated the same coherence value. These types of hierarchies, which were rejected, tended to occur only when the number of chapter sections was very small.
- The number of sections per chapter should not be too large. Several chapters with more than 10 sections were analyzed and rejected because the numbers of sequences permitted by their hierarchies were too large to be counted by my computer in a reasonable length of time.
- The analysis of prerequisite relations in the chapter should permit an unequivocal determination of its hierarchical structure. Several chapters were rejected on these grounds.

It is important to note that chapters were never rejected after calculation of coherence values, except in those few cases in which all traversals generated the same coherence value.

Table 1. Prerequisite coherence of 12 textbook chapters.

					Percentile of actual sequence			
Text		Chapter	Sections	Sequences	$D^{(1)}$	$D^{(2)}$	$D^{(3)}$	$D^{(4)}$
Dorin et al. (1989) high school chemistry	1	chapter 9 chemical equations	13	40734	75	99	99	100
	2	chapter 19 acids, bases, salts	12	20228	73	42	79	98
Duncan (1982) high school physics	3	chapter 9 fluids at rest	13	180469	100	100	99	69
Fisher (1977) college discrete mathematics	4	chapter 3 graph theory	9	38	100	100	100	97
Kalish et al. (1980) college logic	5	chapter 2 propositional logic	9	35	94	94	99	86
Moyer & Bishop (1986) high school general science	6	chapter 10 mechanics	8	576	98	97	98	98
Smoot et al. (1987) high school chemistry	7	chapter 12 chemical bonding	10	900	94	89	93	83
	8	chapter 20 thermodynamics	10	6	—	—	100	80
Stanat & McAllister (1977) college discrete mathematics	9	chapter 3 binary relations	7	12	95	95	91	77
Streeter & Alexander (1989) arithmetic for adult learners	10	chapter 5 fractions	6	20	97	100	100	92
Zumdahl (1989) college chemistry	11	chapter 3 stoichiometry	9	81	100	100	100	99
	12	chapter 4 chemical reactions	12	42690	94	100	100	100

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Results

Table 1 shows the four prerequisite coherence values for each of the 12 chapters. The table also indicates the general content of the textbook, the number and content of the chapter, the number of sections in the chapter, and the number of sequences permitted by the learning hierarchy. Two coherence values are omitted for entry 8 because measures $D^{(1)}$ and $D^{(2)}$ assigned the same coherence value to all 6 sequences permitted by the hierarchy.

The only coherence value falling below the median is measure $D^{(2)}$ of entry 2. Other measures produced high coherence values for that chapter. Most of the chapters exhibited coherence close to the maximum value.

If textbook authors were indifferent to prerequisite coherence we would expect coherence values to fall above and below 50 with equal likelihood (recall that our measure is a percentile). Chi-Square analysis permits a rejection of the indifference hypothesis with respect to all four measures:

$D^{(1)}$	$\chi^2 = 11.0$, $p < .001$
$D^{(2)}$	$\chi^2 = 7.4$, $p < .01$
$D^{(3)}$ and $D^{(4)}$	$\chi^2 = 12.0$, $p < .001$

If only one chapter is allowed per textbook in the interests of independent sampling, then significance is still obtained for all measures ($p < .05$).

Evidence for differences in reliability among the four measures of prerequisite coherence is considerably weaker. There are few cases where the measures show marked disagreement; and no consistent pattern of discrepancy is apparent.

Discussion

The results indicated a tendency among textbook authors to deploy instructional sequences with prerequisite coherence far greater than that expected from random traversal of the underlying prerequisite hierarchy. The question remains whether this tendency figures prominently in the instructional planning of authors, or whether it emerges as an inconsequential side effect of some separate process. Evidence that learning is facilitated by highly coherent sequences would support both the primary conclusion that prerequisite coherence is a fundamental property of effective instruction, and the secondary conclusion that it receives the direct attention of textbook authors.

Finding the most coherent sequence for a sizable hierarchy is generally an intractable search problem for even very powerful computers. This being so, how are authors able to generate highly coherent sequences of chapter sections? Further analysis of the chapters listed in Table 1 indicated that authors rarely deviated from a depth-first traversal of the learning hierarchy. While falling short of perfection, depth-first traversal can routinely generate highly coherent sequences.

In this context, depth-first traversal means that after completing an objective i the author proceeds with another objective j such that i is an immediate prerequisite of j. The depth-first strategy does not always fully determine the sequence because an objective may have more than one prerequisite. A major practical advantage of depth-first traversal is that it requires only local knowledge of the hierarchy. In other words, the author need not be aware of the entire hierarchy as she chooses the next objective in the sequence — only prerequisite links emanating from recently presented objectives are of concern.

Prerequisite coherence is readily applicable to a range of computer-based instructional systems. It is a simple matter to devise hierarchy searching programs that generate sequences with higher prerequisite coherence than those typically chosen by authors. As long as a learning hierarchy is available, such programs can suggest one or more sequences to a course author, a student, or an automated planning module. The program searching for coherence can continue its work while the student progresses through the hierarchy, modifying its recommendations according to the learning times and sequence actually experienced by the student.

The most fundamental conclusion drawn by MacMillan, Emme and Berkowitz (1988, p. 244) in their analysis of problems faced by intelligent instructional planners was that "instructional planning is an underspecified process in a large planning space". In this regard, the principle of prerequisite coherence can be wielded by planners as a widely applicable criterion for constraining search through the instructional planning space.

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Delivering Multimedia Lectures via Fiber Optic Two-Way Interactive Video

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Abstract: Fiber optic two-way interactive video (ITV) courses for rural Western Kansas were planned as technician-supported endeavors. Multimedia, videotape clips and special effects would be generated by a technician. This plan, however, would have disrupted course development cycles for some faculty. The primary author had used multimedia in traditional classrooms; how could this technology be brought into the ITV classroom? The solution included merging existing technologies of multimedia and ITV. Differences between technology-driven and needs-driven planning are discussed. The solution required partnerships; departments that supported or augmented merging included: *Nursing, Computer Information Systems & Quantitative Methods, Information Networking & Telecommunications,* the *Computing Center,* and *Forsyth Library.* The paper describes the partnerships, how the technologies were merged, and how the problem was solved. A short videotape "Longitudinal Study: ITV-ship" shows segments of electronic classroom instruction from graduate nursing courses, covering a one-year period. Discussion includes how to develop multimedia presentations that will also work for future ITV.

Fort Hays State University (FHSU) completed an electronic classroom in 1992 for two-way fiber optic interactive video (ITV) distance learning. The impetus for this paper came when the primary author prepared for ITV delivery to nurses in rural western Kansas. She had been using multimedia lectures in traditional classrooms. How could this type of interactivity be brought into the electronic classroom and how would it need to change for ITV? During the first ITV semester at FHSU, the primary author used the system for an *on-campus* course in order to learn to use the system and optimize course planning for the following semester. Support resources naturally concentrated on courses being delivered to distance sites; therefore, minimal support was available to simply learn the ITV system. Partnerships with The Computer Information Systems & Quantitative Methods (second author) and the Information Networking & Telecommunications (third author) provided significant support (learn-as-you go) for the successes enjoyed the following semester when the primary author's delivery moved *off-campus.*

The paper describes fiber optic technology, the history of ITV at FHSU, the partnerships that developed, and transformation stages. Discussion includes how the primary author adjusted to ITV delivery and how to plan for future ITV courses.

Fiber Optic Technology

There have been numerous transmission media used throughout the modern age; the most conventional are metallic twisted-pair, coaxial cable and wave guides. When evaluating these systems performance standards come to mind: how much information can pass per second, and the distance information can go before reamplification is required. The major limitation of traditional analog systems has been limited bandwidth; and information must be repeated or reamplified every ten miles. For long distance communication, copper-based systems and microwave technology were the only available transmission media until the gradual implementation of fiber optics in the 1980s.

Corning Glass Works developed the first feasible fiber optic strands in 1970. These fiber strands had attenuation values (energy decay) of less than 20 dB/km. This was improved to 4 dB/km by 1972. Current fiber

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optic manufacturing techniques achieved a value of less than 0.2dB/km. Over one million kilometers of single mode fiber had been installed by 1987.

Optical photonics uses a fiber optic strand that is composed of two simple and basic parts: "a core material and cladding made of an optically transparent material (such as fused silica glass) and a coating. The strand of fiber optic cable is made of silica glass and is between 0.0002 inches and 0.004 inches in diameter. This is roughly the same thickness of the human hair" (Jacobi, 1993). The core is the center of the strand and is used to guide the light.

The core is evaluated by determining the relationship of the core to the wavelength of the signal. It is specified by either being smaller or larger than the signal's sine wave. If the signal's frequency is the same as the core then it is referred to as single mode. Cable with a larger core is called multi-mode and has exceptional bandwidth. When compared, copper wire that can carry 24 voice channels is greatly inferior to fiber optic's 15,000 voice channels per strand. It is anticipated that channels will be increased to a half-million in the future. In addition, fiber can also carry over 160 video channels compared to coaxial cable's 78. More advantages of the fiber cable are its easy maintenance, increased service life and resistance to stray radio frequency signals when compared to metal-based media. The partnerships necessary to bring fiber to FHSU were numerous and diverse.

History of ITV at FHSU

Fort Hays State University is a small regional institution in western Kansas with a 44-county services area. The annual enrollment is just under 6,000 students. FHSU is the only four-year liberal arts college in the western half of the state (50,000 square-mile service area). The problem for distance learning delivery is compounded by the fact that the service area represents almost half of the land mass of Kansas but less than one-third of its total population.

Many of the small rural unified school districts in the center of these communities were finding it increasingly difficult to maintain the quality of elementary and secondary instruction. The Kansas Legislature and the Department of Education have been in the process of raising standards for secondary schools, to provide a quality-based education and insure that the proper courses for college entrance requirements are taught. These competencies range from foreign language to art and science. In addition, many schools faced the harsh reality of consolidation with other rural districts. The local *esprit de corp* is influenced by the success or failure of local high school sports teams as well as the academic achievements of the sons, daughters and friends attending the schools.

As a way to insure the longevity of both the rural school and its community, the secondary schools in the district decided to pool resources. This would provide for the purchases and installation of a technological infrastructure that would allow one teacher to concurrently teach for more than one school at a time. Driving from site to site was not practical; the distance between schools could easily exceed 60 miles.

Public and private partnerships developed among the various school districts and the local independent telephone exchanges. Community cable systems provided a unified front with a common goal. The goal was to provide a secure environment for learning, a sharing of resources, and the development of a diversified curriculum while preserving the rural community and its schools. The first fiber optic cluster was activated in the fall semester of 1990. Since then, three new clusters became operational to make a total of seven. The results have been favorable, with courses in foreign language, biology and mathematics being taught concurrently from one school to a combination of three others.

At the time when much of the planning for the development of Unified School District (USD) fiber clusters was taking place, two cellular telephone franchises were being awarded to the state. One, Kansas Independent Networks Incorporated (KINI), was a consortium developed by some of the independent telephone networks. Most are located in central and western Kansas. Kansas Cellular decided that by connecting the individual cell sites with twelve-strand fiber, adequate bandwidth for growth would provide communication highways for education, business, and healthcare agencies. The construction of a point-of-presence on the campus provided the fiber optic trunk line needed to connect the school clusters to FHSU.

In January of 1992, courses in special education and philosophy were offered to the Interactive Consortium Academic Network (ICAN). ICAN's fiber optic analog circuit terminated at the Rural Telephone Company "pop" in Victoria, 11 miles from the FHSU campus. At that time, ICAN was the newest fiber optic cluster in the state and was of the first to embrace the idea of using off-hours as a way to offer college-credit classes. During the first semester, enrollment was sparse. However, the university administration determined it would take time for ITV to be accepted. A firm commitment was made to maintain an aggressive posture in the development of new classes and to offer degree programs that students could take without having to step foot on the Hays campus.

The following fall, KINI completed a fiber optic trunk line south to Dodge City. As one of the largest population centers in the service, Dodge had no upper-division college-level courses. It also had the distinction of being the first fiber optic cluster formed in the state. The High Southwest Plains Network (HSPN) included sites as far south as the Oklahoma border. It was immediately followed by the A-Plus network. There is a combined total of twenty sites in the south-central Kansas area. Prior to completion of the interactive gateway, FHSU approved the funding necessary to complete the construction of an interactive electronic classroom. At present, FHSU is an associate member of HSPN and is offering a diverse schedule of upper-division undergraduate and graduate courses. The enrollment of the ICAN and HSPN ITV courses steadily increases each year.

Partnerships

Anderson and Kimber (1991) wrote about meeting continuing education (CE) needs or rural nurses. They pointed out that rural nurses see themselves as cut off from the professional mainstream. The primary author determined to create an ITV environment that would make the nurses feel comfortable. Shomaker (1993) states it is vital to modify student and faculty support services on campus for use with distance learners. The challenge was to determine what to modify and what support services were needed. Authors such as Clark (1993) note the reward for meeting ITV challenges is satisfied distance learners. Such was the goal of the primary author as she planned multimedia lectures adapted for ITV.

Considerable effort had been expended on *off-campus* partnerships to support ITV delivery; little thought had been devoted toward *on-campus* partnerships. The ITV environment at FHSU was planned to use multimedia such as Amiga graphics, videotape clips and special effects that were to be generated and/or supported by a technician. This plan, however, would have disrupted course development cycles for some faculty, including the primary author. Partnerships began to form.

Faculty are used to lecturing in a traditional environment (that *looks* like a classroom). The technology orientation of the ITV support staff caused the electronic classroom to look and function much like a TV studio. The Amiga computer was placed in the control room in the back, for technician use. The faculty bunker had no computer and limited space to put faculty notes, props, etc. A request was approved by the Provost and sent to the Computing Center to install a computer for the faculty "bunker" (front of the classroom); space was made and a 386 installed rather quickly. An ISN connection to the mainframe was then requested and installed. The Telecommunications staff purchased and mounted a notes holder to assist with lectures. The bunker was then much easier to use.

Moving from traditional to ITV lectures requires a mapping process: a TV-like storyboard that blocks the time and gives the technician specific instructions. Faculty are not *used* to handing a plan to someone before every lecture. They are also not used to using multimedia in a technician-supported electronic classroom. Multimedia is the delivery of information, usually via personal computer, that combines different formats, including text, graphics, audio, still images, animation, and motion video (Miller, Sayers, Reeve & Kasten, 1991). If faculty get involved in creating their own multimedia presentations, the outcomes are strengthened. The creative process is further strengthened for some faculty by developing "on the fly" but support is still necessary and important.

The electronic classroom was used to turn multimedia lectures into ITV presentations, with its SkyCam (ceiling camera), 386 computer and computer-based 16 mm. slide projector. Fred Hofstetter (IBM Scholar, University of Delaware) points out that faculty tend to get the lecture ready at 10:30 the night before. Ultimately the faculty in charge of the course is responsible for the lecture. If there is a last minute handout, one copy can be faxed to each site from the faculty bunker. The activities may sound easy, but they take numerous partners to make it all happen. For example, faxing is done by the classroom technician. To access the on-line library catalog during class, the Computing Center's ISN connection is available. It allows access to the E-Mail system (OfficeVision), Internet and other computer mainframe features. Faculty may demonstrate these resources on-line across the plains of Kansas for a *different* kind of multimedia lecture. An additional Computing Center resource that supported ITV was the computer-based voice mail system (interactive audio). Students who thought of questions after class left digitized voice messages that were answered in real time by faculty.

One unanticipated area was requests from students for lecture videotapes. When a student missed class, for example, due to illness, she wanted to experience the ITV lecture (there were no men in the ITV classes). Th reserve videotape at the FHSU library did not help a distance learner. The logistics of faculty management to mail videotapes was time consuming; eventually, students were asked to arrange for videotaping to take place at the local high school site during class. All sites had a VCR but not all of these were in working condition. Local partnership work was needed to get all VCRs working; the results were satisfactory.

Technology-Driven vs. Needs-Driven

The integration of technology into traditional teaching schemes is one that must be accomplished with sufficient planning. The design should be scientifically developed and installed after appropriate assessments have been completed, marketing strategies devised, and needs evaluated.

The importance of instructional design cannot be overstated. The reason that technological integration should grow out of an instructional design model is that assessment of the learning context, needs analysis and student evaluations (the heart of traditional instruction) are not less important with ITV. Instructional design rather than technology design is the standard by which all interactive systems should be measured during preplanning, construction and integration into the academic mainstream.

Increasing the synthesis of information does little unless faculty understand that intelligence models do not change but require a new set of parameters in which to operate. Introducing new presentation forms could actually impede the process if learning strategies do not take into account the strengths and weaknesses of the media. The technology should become transparent to both the faculty and the student. Developing a technologically sophisticated delivery system provides little benefit if the message that is delivered is unimportant, distorted or lost in a world of technical jargon.

The development of learning objectives is the area of planning that provides a foundation for all other units of the instructional design scheme and technology planning. A learning objective is an operational description of an anticipated change in the behavior of a student after exposure to instruction. It states exactly what it is that the faculty expects the student to be able do as a result of having learned something (Cyrs & Smith, 1990).

Therefore, it is important that the learning environment design flows from: the learning context, student assessment, task analysis, learning objectives, and self-assessment. These instructional design components should be implemented *before* the cameras, computers, and television monitors are installed. Faculty at FHSU attempted to do this, but got bogged down in the technology itself. A course evaluation tool created by the Instructional Media Committee was one of the few components prepared ahead of time.

The situation as it occurred at FHSU supports the need for design components. Much attention was placed upon the development of fiber optic connectivity, the construction of the electronic classroom, and the attempt to connect to as many distant sites as possible (seven sites can be connected concurrently for one class). Little attention was devoted to faculty development, instructional design, or curriculum development. The system struggled for over a year before a scheme developed for faculty training and support. The President established an *Information Management Task Force* to study information problems (two of the authors, M. R. Hassett & M. Leikam, were task force members). Out of this study came the new *Center for Teaching Excellence and Learning Technology*.

How One Faculty Adjusted

A short videotape "Longitudinal Study: ITV-ship" (Hassett, Leikam & Jarmer, 1992) shows representative segments of electronic classroom instruction from two graduate nursing courses, covering a one-year period. The electronic classroom was intimidating at first; one must pay attention to the subject matter and the new technology. The primary author evaluated her performance by keeping a weekly anecdotal record. At first, this was painful. However, problems were identified early-on for which partnerships could assist. Some mistakes shown on the videotape include:

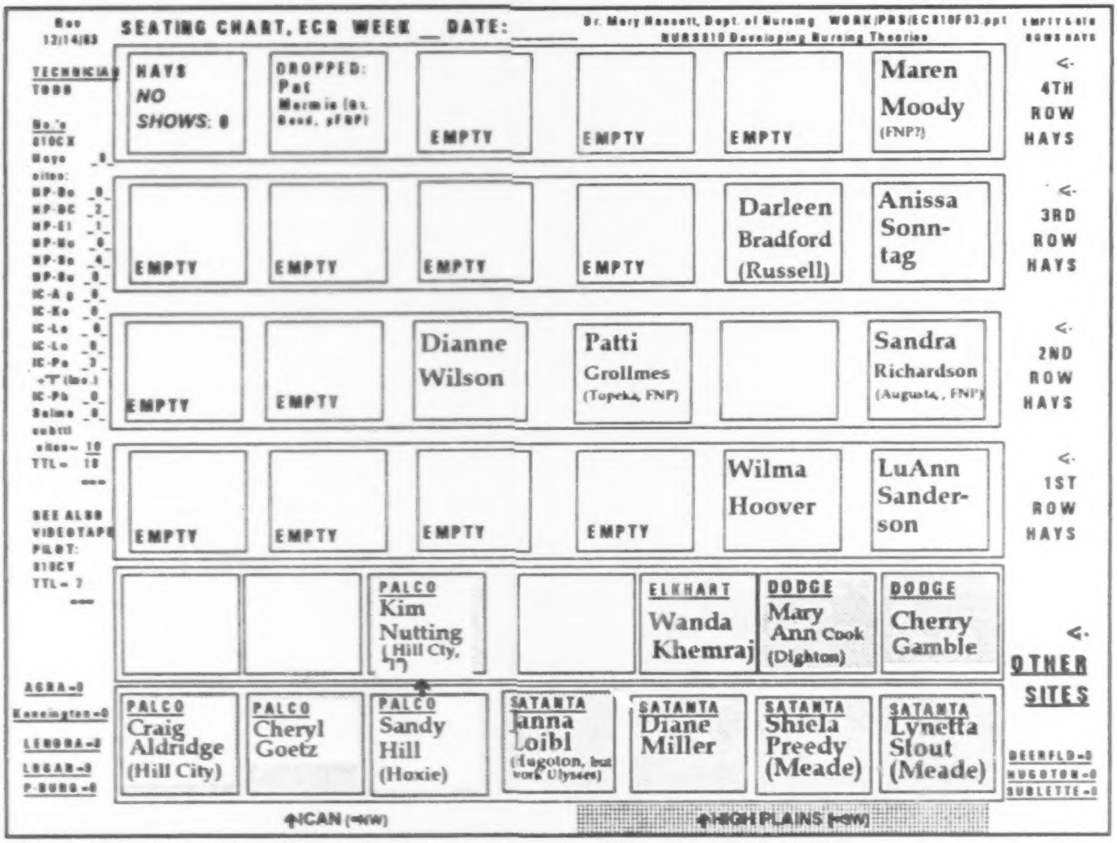
- had to use chalk board because did not know to bring colored pens and paper for SkyCam,
- did not look at camera,
- wore wrong color (chromakey showed text across abdomen), and
- did not control lecture notes pages.

Gradually, performance improved and there were fewer problems with delivery. Feedback from the review of videotapes and the student feedback was helpful. (It would have been good to also receive feedback from the assigned technician.) Some positive behaviors shown on the videotape include:

- controlled lecture notes,
- looked at camera more often,
- relaxed and smiled more,
- wore right colors,
- had pockets in clothing (for wireless microphone), and
- called on students by name (instead of saying, *e.g.*, "Dodge City").

It is very difficult to recall names from several sites and to recall which student is at which site, all the while keeping calm! Therefore, an old-fashioned seating chart was used with the names of students for each site (see Figure 1). The chart was used during each lecture to help keep the class active (rather than seeing a *talking head* faculty).

A question that came to mind was: Should ITV episodes be called "lectures"? "Video forums" may be a more appropriate term..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Darleen Bradford (Russell)
Anissa Sonn-tag
<- 3RD ROW HAYS
Dianne Wilson
Patti Grollmes (Topeka, FNP)
Sandra Richardson (Augusta, FNP)
<- 2ND ROW HAYS
Wilma Hoover
LuAnn Sander-son
<- 1ST ROW HAYS
SEE ALSO VIDEOTAPE
PALCO Kim Nutting (Hill Cty)
ELKHART Wanda Khemraj
DODGE Mary Ann Cook (Dighton)
DODGE Cherry Gamble
<- OTHER SITES
PALCO Craig Aldridge (Hill City)
PALCO Cheryl Goetz
PALCO Sandy Hill (Hoxie)
SATANTA Janna Loibl (Hugoton, but work Ulysses)
SATANTA Diane Miller
SATANTA Shiela Preedy (Meade)
SATANTA Lynetta Stout (Meade)
ICAN (+NW)
HIGH PLAINS (+SW)

Figure 1. ITV Seating Chart, Developing Nursing Theories, Fall 1993

Benefits for Faculty

Tools used to evaluate were: a questionnaire written by the campus-wide Instructional Media Committee, and anecdotal note pages for faculty (documenting what appeared to work and what did not and validating later).

This method was used for four semesters (the first semester course did not go off-campus but the ITV classroom was used as if it were).

If faculty do not perceive benefit to themselves as busy people, technology may be ignored. Some faculty are skittish about offering an ITV course; one recently said "I don't want people across Western Kansas to see that my new course isn't well developed." Faculty benefits include:

- decreased "windshield time" driving to and from distant sites,
- immediate feedback *to* and *from* students,
- satisfaction at being able to do a better job, and
- preparation for the future.

The primary author found the biggest benefit was the way ITV helped develop better lectures than ever before. There was not much space for *informal* creating of lecture material. ITV forced her to be a better teacher/facilitator. (A regular classroom now seems dull.) Collegiality among the partners was an additional benefit.

Benefits for Learners

Student uses parallel those of faculty and benefits include:

- decreased "windshield time" driving to and from the university classroom,
- immediate feedback to and from faculty,
- immediate feedback to and from other students, and
- preparation for the future.

The immediate feedback on video is *startling* in the way it facilitates student learning. A picture is worth a thousand words. Feedback from other students was important; one international student particularly seemed to benefit (her native language is Chinese). Her participation level was higher with ITV than was usual for a regular class. Student networking was facilitated, particularly among those at the same site.

Transformation Stages

The electronic classroom is the last of the transformation stages (Hassett, 1993). **Opaque** was our first stage of transformation in teaching with technology: it means *impenetrable by light*, or *dull*. Technology in the past was opaque; one could not see through it because of barriers. Opaque examples include: blackboards, low intensity overhead projectors with light bulbs dying on a regular basis, and very little use of color.

Translucent means *transfusing light but diffusing it to cause images to become blurred*. Today, we are primarily in this stage, in the distractor mode. We partners tried laying a portable computer under the SkyCam in an early ITV class to show output (video feed scrolled and crawled). One piece of technology changed that: when the genlock was acquired, the scrolling stopped and output to the classroom monitors became clear as a fine TV set. . . that is, it became transparent.

Transparent means *capable of transmitting light so that objects on the other side can be seen*. What is wanted for the learner is to see through the technology without even noticing the technology is there, in the enabler mode. A graduate student who uses the Dodge City site shared after the second week of ITV that she did not notice the video camera any more: "I felt like I was in the classroom with you."

Planning for Future ITV Courses

Only a few faculty are presently doing ITV. How should the multimedia lectures of today be developed so they will also work for future ITV? The primary author learned to storyboard each lecture for the technician in the control room. This was new and required additional time but strengthened lectures. How many faculty have to show a detailed plan to anyone before doing a lecture? For ITV, one does it every time. Faculty do not have to wait for *ITV* to storyboard; the technique would work for any course.

It took the primary author three to six hours per electronic classroom scheduled clock hour to prepare an ITV class. FHSU compresses two ITV clock hours each week for a three credit hour class; therefore, it took 9 to 12 clock hours per week to prepare (for an already developed course). Initial outlay of time is extraordinary! Tips for ITV include:

- have back-up material ready (*e.g.*, keep extra material nearby in case something goes *haywire*),
- minimize distracting mannerisms,
- send handouts 10 days ahead (use a lecture packet students purchase from the campus book store if possible), and
- do not be too serious (smile more)!

And if the technology fails or acts up, do not apologize--IMPROVISE. ITV prepares one for the future when this type of communication will be common. Examples could include:

- ITV consultation for a Family Nurse Practitioner in Ransom, Kansas and a physician at The University of Kansas Medical Center,
- ITV nurse administrator meetings for consortia activity,
- ITV continuing education for rural clinical nurse specialists,
- ITV statewide professional society meetings, and
- ITV consultations with a master teacher at FHSU for a community college faculty.

A number of the graduate students taking ITV classes had a computer available to them. In the future, rural students may be *required* to have their own computers. Many urban universities already require this.

We found that success for ITV in the sparsely populated FHSU service area requires offering complete degree programs. Other examples include classes for: teacher recertification, nursing relicensure, and workforce retraining. The Master of Science in Nursing program has been highly successful because of demand and a distance learning delivery that meets the needs of place-bound working nurses. FHSU was not successful in offering courses that did not fit into a planned curriculum or that could not result in the completion of an undergraduate or graduate degree.

Support for delivery of ITV courses is complicated. Merging the existing technologies of multimedia with ITV required partnerships. The departments used to support or augment merging included: *Nursing, Computer Information Systems & Quantitative Methods, Information Networking & Telecommunications,* the *Computing Center,* and *Forsyth Library.* These partnerships strengthened the ITV offerings and the relationships among the partners.

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Shapiro, A.F., Gibbs, W.J. & Hall, S.H. (1994). An approach to multimedia for the continuing education of actuaries . In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 92-95). Nashville, Tennessee: Omni Press.

An Approach to Multimedia for the Continuing Education of Actuaries

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Abstract: This paper reports the results of a joint venture by the Society of Actuaries and Penn State University to investigate the effectiveness of a computer-based multimedia platform for the continuing education of actuaries. The goal of the project was to produce a prototype multimedia module for continuing education and to have it evaluated by practicing actuaries.

The participants' reviews of the program were very favorable. The majority indicated that the multimedia presentation was worthwhile and that they would recommend the multimedia delivery system to their employers.

Introduction

Last fall, the Society of Actuaries and Penn State University undertook a study to investigate the effectiveness of a computer-based multimedia platform for continuing education. Among other things, multimedia was being examined as a potential means to overcome the limitations of instructional video tapes. The goal was to produce a prototype multimedia module for continuing education and to have it evaluated by practicing actuaries.

A current taxation issue was chosen as the topic for the prototype and the Chief of the Actuarial Branch of the IRS was chosen as the content expert. The prototype was then tested at two Society meetings: the annual meeting in Washington, in October, 1992, and the spring meeting in San Diego, in April, 1993. The advantage of using Society meetings as test sites was that testing and evaluation could be done by potential users without their having to purchase equipment or incur any cost.

The participants' reviews of the program were very favorable. The majority indicated that the multimedia presentation was worthwhile and that they would recommend the multimedia delivery system to their employers.

This article discusses some advantages of a multimedia platform over instructional video tapes and reports on the opinions of the actuaries who participated in the multimedia sessions.

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Why is Multimedia a Good Educational Tool?

Everyone studies and learns in a different way and at a different pace. Multimedia is a good educational tool because it is well suited to accommodate these characteristics; it allows users to proceed through the material in the way that best suits their needs (Jonassen, 1991). For example, users do not have to proceed linearly through lessons. They can skip previously learned lesson segments, move forward at their own pace, and review when necessary.

Comparison with Video Tapes

Video tape, while appropriate for many instructional applications and situations, is limited because it is not interactive and it presents information in a continuous, linear fashion (Hannafin & Peck, 1989). One purpose of this project was to examine multimedia as a potential means with which to circumvent these limitations of instructional video tapes.

Since video tape is not interactive, there is no opportunity for users to provide input. Consequently, performance cannot be monitored and instruction cannot be adapted to the user. For example, there is no way to determine whether a user misunderstands a concept and needs review or understands a subject and should advance to the next lesson.

Video tape does not allow instant access to information. Users, when deciding to skip a previously learned topic cannot do so without fast-forwarding or rewinding the tape, which is a relatively slow and inefficient process. The instant access to information available in a multimedia system should encourage learners to go back and review a trouble spot, whereas the difficulty of finding the right spot on a video tape might discourage them from doing so. A related problem is that in the time it takes to search for a specific lesson segment, the reason for the search may no longer be clear.

Advantages of Multimedia

The multimedia prototype provides several important advantages to the users.

Multimedia gives users the ability to jump to a specific topic at will. Users are not subject to a continuous flow of information from beginning to end, but rather they have instant (random) access to and control over the information (Magarry, 1988; Jonassen, 1991). The result is that individual learning rates and styles are better accommodated.

Multimedia facilitates interaction with the lesson. In addition to choosing how to proceed through the lesson, users can respond to questions, manipulate objects, and input numeric values into tables. These activities are included in the lesson to promote learning. As many researchers have noted, the acquisition and retention of information is more likely to occur when the learner is actively involved with instruction rather than being a passive recipient of it (Hannafin & Peck, 1989; Cennamo, Savenye & Smith, 1991).

Testing is design to ensure that important concepts are learned by all program users and to alleviate the fear of failure often associated with conventional instruction and assessment. For example, review questions are presented after each content segment. As users respond to questions, the multimedia system monitors their responses and coaches them to formulate correct answers. Incorrect answers are detected by the system and feedback and remediation given, to help the user derive a better understanding of the concept.

Finally, multimedia lesson materials are integrated into a single computer-based platform. This gives users control over a host of instructional resources and make all the advantages of multimedia discussed above possible.

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Evaluation of the Multimedia Platform

The prototype was evaluated by 21 actuaries at the annual meeting in Washington and by 26 actuaries at the spring meeting in San Diego. These numbers so not reflect the people who signed up for the session but could not be accommodated. In San diego, for example, 55 individuals were wait listed. The assessments at the Washington meeting (see Shapiro, Gibbs, & Hall, 1992), were consistent with the favorable assessments given in San Diego and reported below.

At the San Diego meeting, participants were asked to assess the effectiveness of the multimedia presentation format by responding to several statements. Participants rated the program on a 5 point scale, where 5 corresponded to Strongly Agree and 1 corresponded to Strongly Disagree. A summary of the responses to these questions is shown in Table 1.

Table 1
Participant Reactions to Presentational Format

Reaction Statement	**strongly agree**		**Neutral**		**strongly disagree**
	5	**4**	**3**	**2**	**1**
The presentation was well organized.	71%	29%			
Visual materials were appropriate and enhanced the presentation.	83%	17%			
This was the appropriate format for presentation of this topic.	58%	25%	17%		
My time was well spent attending this session	38%	46%	13%	4%	

Numbers may not add to 100% due to rounding.

In addition, participants were asked to answer the questions shown in Table 2. For comparison, the Washington results ("D.C." columns) are shown in addition to the San Diego results ("S.D." columns). The results show that the majority of participants at both meetings responded favorably to the delivery system. Over 90 percent enjoyed the delivery system and thought that other programs should be developed, and 80 percent said they would recommend the delivery system to their employers.

Table 2
Participants Overall Reactions

	Yes		No		Sort of		Indifferent		No Response	
	D.C.	S.D.	D.C.	S.D.	D.C.	S.D.	D.C.	S.D.	D.C.	S.D.
Did you enjoy this delivery system?	90%	96%		4%	5%		5%			
Should other programs be developed using this delivery system?	90%	96%					5%	4%	5%	
Would you recommend this delivery system to your employer for use within the company?	81%	78%	5%	13%					14%	9%

Participants had an opportunity, after each session, to write their reactions to the prototype. A summary of comments from both meetings is listed below:

Shapiro, A.F., Gibbs, W.J. & Hall, S.H. (1994). An approach to multimedia for the continuing education of actuaries. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 92-95). Nashville, Tennessee: Omni Press.

"It involves the student (me); it is participatory and this causes it to be more enjoyable and more effective [then] lectures."

"I like it because I could control the time/instruction. If I missed something I can rerun it again. Its Great!"

"Quiz is helpful in sustaining attention. I like the fact that you could replay something you didn't understand the first time."

"I found the multimedia, individually oriented, quite interesting and well done. I can go at my own speed."

"Multimedia engages multiple senses."

"Fantastic Graphics!"

Conclusion

The attractive characteristics of multimedia - such as, self-directed and self-paced learning, lesson interaction, dynamic testing and instant access to information - combine to create an ideal learning environment and help to overcome the limitations of instructional video tapes. From the experience at both the Washington and San Diego meetings, it appears that this environment is well suited to the needs and preferences of the modern actuary. Therefore, it seems inevitable that multimedia will play a significant role in the continuing education of actuaries.

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Bussolin, G. & Bruno, A. (1994). A project for computer supported learning in the field of administration sciences. The use of hypertext techniqyes as a guideline for its design. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 96-102). Nashville, Tennessee: Omni Press.

A project for computer supported learning in the field of the Administration Sciences . The use of hypertext techniques as a guideline for its design.

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Abstract: This project is in progress and concerns the computer supported teaching and learning of " Finance " in courses at university level (Faculty of Economics and Business Administration School).The design development strategy of the project is based on a joint venture by a variety of experts and students at the level of degree dissertation . One of the outputs of the project is a running computer-based tool for P.C.'s (hypertext software-based tool). This tool has two "modes" of use: The "teaching mode" , i.e. the mode for the speaker's lectures (Professor of "Finance"); and the "learning mode" , i.e. the mode for the Learner, the free use on the part of the student. The theoretical foundation of the model, its design and its first results are discussed.

Introduction.

As explained in the abstract of this paper we will deal with a project in progress. Within this project a given prototype running on Macintosh computers has been realised, and a certain number of users has already used the program itself. We are now hoping to realise a more widespread use of it for many students during the present academic year . According our experience and predictions, we expect to collect new and interesting results in order to enhance this product, to improve the model and above all to enrich our scientific knowledge.

The word "system" will often be employed in a broader sense to indicate an arrangement of individuals and things so related or connected as to form a unity or organic whole. The term "project" will be used to indicate the planning state or condition of the system under discussion. This arrangement of things will obviously include hard and software , i.e., computers and above all software prototypes as output of the human activities put into effect during the planning activities. The word "model" will be used in its precise meaning of representation and design (Bussolin,1992).

The name of this project (Hyper Finance), as may easily be understood, comes from the combination of the two words "hypercard" and "finance". In fact, this prototype has been realised in the hypercard environment, has been written with hypertalk language, and its purpose is the teaching of Finance within the courses of the Faculty of Economics of the University of Torino, and the courses of the Business Administration School of that University .

Part 1. Theoretical and conceptual foundation of the project. Some considerations on its guidelines and its principles.

Before dealing with this project in a more analytical way, it seems to be very important to reflect on its foundations and to make some considerations which lie at the base of the whole work and which justify, we may say, the choices made throughout the process of its construction. These reflections and considerations will be set out in random order, therefore without precise priority , as they belong to different orders of thought and to different scientific fields.

The first point from which many considerations follow, might be titled: the "human side of the sciences of design and of the sciences of projects". The idea of utilising the techniques of hypertexts and a given software in

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order to realise a prototype running on a personal computer for the teaching in a business administration course is not really a new one: some realisations exist in this field, even if they are not numerous (Ruggero, 1993).

It seems to us that, given the above mentioned considerations, it is worth remembering how the "human side" has played and will play an even more definite role, a role that strongly influences the success of a project of such a nature. As a key to the interpretation of this side, the whole thinking of H. A. Simon is significant, particularly certain of his works which will be cited from time to time.

There is often talk about the barriers to the penetration and implementation of the new instructional technologies (Postero,1992), as there is, in general, about the use of this computer technology in the world of human organisations, the world of profit and non- profit organisations.

During the course of this project, we have frequently noticed how in the field of computer-based education, as one moves towards higher levels of teaching, one encounters specific and perhaps greater difficulties, and specific and perhaps greater barriers of a different nature. We have noticed how the applications in the different fields of science are not uniformly distributed (Ruggero, 1993). Particularly in the field of Economics, of Administration Science, the implemented tools for computer- based training and education are extremely scarce (i.e. in number) for the University levels in comparison the remaining fields. An investigation concerning the why's of this state of affairs probably might lead us out of the precise domain of exposition that we have undertaken. Nevertheless, some considerations may be offered.

Within the domain of the literature concerning the use of information technology for education it seems to us that the two aspects of a single problem are not taken into precise account , mainly as regards the computer tools as a teaching aid: the Teacher's aspect and the Student's aspect. Most attention is paid, and most scientific considerations are dedicated to the sphere of behavior and the knowledge domain of the Learner, i.e. the person who benefits, the person who makes use, as receiver, of the scientific communication based on and supported by the information technology. Normally the "hows" of this learning process are investigated in respect of and according to the changing of many conditions, in conformity with the technology contingently being used, in accordance with the modes of its use. One of the most important purposes of these researches is that of improving the "quality" of learning (Bussolin,1992). According to our thinking, it seems that the theme for the development of this technology for teaching, for education, concerns equally, in the first instance, not only the learning processes of the Student, but also the cognitive processes of the Teacher who must, or wants to or may use this technology.

As a first approximation, it seems that the cognitive processes involved or to be developed for the Teacher are by far more complex and offer greater barriers and difficulties than those encountered for learning on the part of the Student. Normally, for the Learner it is the "quality" of learning which promotes the use of this technology (without for the moment analysing the complex meaning of the issue "quality of learning"). For the Teacher, the University Professor , a dual purpose exists : the quality of knowledge that this person has to transmit is involved. In fact , the use of this technology carries with it , often, the task of reshaping the knowledge to be transmitted, the task of systematising the universe of the Teacher's own knowledge, the task of redefining the modes of communication and transmission of his/her own knowledge, etc. etc.

As already mentioned, there are many likenesses among the processes of use of this information technology within organisations in general (see projects of office automation, of decision support systems, of large database systems, etc.) and its use for educational purposes. One of these likenesses or analogies lies certainly in the fact that the side effects of its use always lead us to a redefinition of the state of affairs of the system which is object of the computer-oriented application.

As the educational level increases, always remaining in the field of Economic and Administration Sciences, particularly at the university level, the representations of the knowledge domain to be transmitted become more and more subjective representations, therefore more linked to the personal interpretations that the Lecturer makes for his own discipline to be transmitted. These representations are more and more connected to his personal education culture and background, to the shapes and to the processes according to which this knowledge has been generated in time, to the dynamics of the new elements that the Lecturer decides to add to his own system of knowledge and to the dynamics of the elements that, are to be abandoned. These cognitive studies concerning the processes of generating and storing the knowledge of the Lecturer, must also take into account the propensity of the Lecturer to use this very technology.

Furthermore, the forms of transmission of this knowledge are extremely varied and influenced, to a certain degree, by the organisational environment within which this educational process is being carried on. These shapes of transmissions are closely interwoven with the factual conditions of this environment, with the contingent state of the information technology at hand and the contingent state of the very organization within which a member of it, i.e. the Teacher, acts and behaves. On this subject, we might better say that the project under discussion in this paper, and generally speaking projects of this kind, must keep separate the two following aspects: the cognitive aspect of the Teacher who wishes to use or to improve the use of this information technology, and the aspect of the organizational influences that are the premises to the initial decision to use it, and the premises to the subsequent decisions which will be made when the instructional system is brought into being within the educational organization.

The employment of this technology always involves not only the Teacher or Lecturer who uses it, but the whole university organization or, generally speaking, the whole educational organization, within which the process is being developed. With traditional teaching, the cognitive premises of the teacher and the organizational influences upon him are very much more indefinite, and probably they have been less thoroughly investigated and have given rise to fewer scientific observations in comparison with what happens now , since the educational technologies have come onstage. The study of Computer Based Learning may give fruitful results, both scientific and practical, if we consider the Learner and Teacher as members of a specific organization . In this sense the process of transmission of knowledge may be investigated as a cognitive process belonging to the organizational premises for decision making (Simon,1947; Kleindorfer, Kunreuther & Schoemaker,1993).

Finally, let us stress the importance of the project aspect, i.e. the side of the experimental phase for the construction the Computer Based Learning prototypes, unlike what happens for traditional learning. We have for a CBL project , in fact, a variety of experts who participate in the project: not only the expert on the knowledge domain, and the expert or experts on the information technology, but also the users (Learners and Teachers) who benefit from this project and who may give useful answers and stimuli during the process of experimental use of the software prototypes being constructed. Furthermore, during this project phase, we have the possibility of planning the roles that will be played by the human "agents" and the information technology "elements" according to a variety of modes and shapes, etc. etc. (see Postero, 1993 and works referenced).

Part 2. The development of the project. Considerations around its foundation elements and its first results.

Let us consider now, more closely, the realisation of the project, the elements which compose it, its first results. This second part, also, will be set out according to a list of points in random order which are not in a definite order of priority.

As previously said, the purpose of this project is to develop the teaching at a university level through a new technology for a course in a Faculty of Economics. The principal target is to support the motivation for the use on the part of the Lecturer (a University Professor) and to improve the quality of learning on the part of the students. The construction of these models, and the software prototypes deriving from them is inspired , from the scientific point of view, by the principles of the Artificial Sciences (Simon, 1969) and specifically by the principle according to which the whole project and the model taking shape within it , are so to speak "molded" by the purpose lying at the base of the whole construction.

The following observations may fall within the compass of interfaces as a meeting point between the "inner " environment, i.e. the knowledge of the Teacher to be transmitted, and an "outer" environment, i.e. the learning process of the Students. (Simon,1969). What has been called " model" in our project, might better be understood as the design of such an interface. In the course of this second part of the paper we will be more specifically concerned with the design of such an interface.

Given the purpose previously and specifically mentioned, a hierarchical shape has been chosen for the hypertextual structure of concepts to be transmitted , discarding the hypothesis of other solutions well known in the literature (Conklin, 1987)(Van Dike Parunak,1989).

The hierarchical shape is the most appropriate to realise a gradual process of knowledge so that the Teacher , during the first steps of the project, may obtain a greater confidence toward the use of the computer-based tool . The strongest cognitive representation that a Teacher may have, as regards the subject or discipline taught, and when this teacher has not yet utilised the hypertextual technology, is a hierarchical representation of the concepts belonging to the knowledge domains of his subject or discipline. This issue is , of course, based on our personal and empirical observations from the project carried out and it would be very interesting to evaluate this assumption through more scientific experiments .

For a reason similar to the one previously shown, we have used the "metaphor" of the book . The Teacher and the Student find, in the first images on the screen , the design of a series of books named Riskanalisys, ..., Exercises, User manual, and starting from each book, the navigation may begin . At the end of each book a series of tests may help the Student to measure the degree of learning he/she has attained (Giordano,1993).

The cognitive problem of initiating the Teacher in the use of this technology must be solved for the development of the instructional technology itself . The traditional relationship existing between the Teacher and the book, this last being intended as a hard copy containing his own concepts, and the relationship among the users and the sequential flow of concepts, are very strong traditional cognitive relationships . Only after having learned how to use a hypertextual computer-based tool, will the user accept a new concepts representation based on a free navigation. Under these circumstances, it will therefore be possible to "rewrite" the whole content of the user's knowledge domain through the concepts composing it, organising this domain by a structure based on new shapes of links and new modes of navigation .

The same considerations made with regard to the Teacher's side, may be made now, "mutatis mutandis", with regard to the graduating Students' side, i.e. the members who have participated in the project and in the construction of the model itself. These members may be considered as potential users: they have undertaken a joint venture as bearers of computer science expertise and bearers of administration science expertise . They have shared the purpose of the project and they have given rise to a "mix" of expertises (Spool,1993).

Hierarchical structures of concept, which may be thought of in a logical sense as trees, have been constructed . The elementary concepts (leaves of the trees) represent the minimal units of the model. These minimal units are in a given correspondence with a succession of images on the screen. This analytical approach to representing human knowledge might be considered , " a posteriori", a reductionist approach, while the holistic approach might be considered as the one needed for the generation of links adopted within the structure of the model or during the computer-based user interaction.

As previously said, the metaphor of the book has been used in order to individualize the root of each tree composing the "forest". Each tree individualizes a book, the series of trees individualize a forest. The "forest" may be imagined as the whole course that has to be transmitted to the students.

The first idea of the navigation that may be understood consistently at the beginning of the project, is the idea of a sequential navigation; that is, to read forward and backward the leaves of our trees and to search for the arguments through a hierarchical navigation in order to find the various books, chapters, paragraphs, etc.

Upon the base structure so built it has been possible to initiate (I repeat,"initiate") the "holistic" approach previously mentioned, that is, an approach aiming at the construction of a system of non-hierarchically structured links . This construction is strictly connected with the interface support , i.e. the support giving evidence to the user on the computer screen of the commands (icons, pull down menus, symbols, etc.) which allow the user a different navigation from the sequential one seen previously.

Before speaking about this navigation we would prefer to make brief reference to the problems which arise for the construction of the user interface. Of particular interest for the project have been the "hows", the modes in which the user interfaces have been built, therefore the construction of each screen form. This concept of interface, previously mentioned, is here to be understood in a wide sense, therefore also with regard to the use of a given language, not simply natural, but also symbolic and, above all, a language based on icons, buttons, pull down menus etc..

This last kind of language has a great cognitive potential and , in our project, it allowed us to create specific communication means on the part of the Teacher, and it permitted us to offer specific learning means to the Student. We have previously mentioned the "hows" in which the user interfaces have been built in order to suggest that the use of this "non natural" language has been one of the first steps that the project team (students in Economics and students in Computer Science) have learnt in order to construct these very user interfaces.

It seems to us very important to remember that in a project team, of the nature under discussion, the interface language must reach a consistent and precise level of definition , it has to be learnt and shared by its members and therefore it must be used by them according to a definite system of standards. This last mentioned aspect or moment of the scientific investigation is certainly crucial for the whole success of the project, if we think that the builders themselves are the potential users ! The concept of "bounded rationality" (Simon,1945) has been inextricably interwoven with the process of design realised by the members of the project under discussion. The "rationale" involved within this process must be better investigated in order to give a foundation to the construction of such interfaces.

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The first important function that we faced was that for a traditional reading, therefore the use of buttons for the sequential navigation forward and backward, the map for the cognitive orientation and the icon for the history in order to lessen the cognitive disorientation.

Furthermore we have implemented: 1) buttons for the "static" and the "dynamic" deepening of concepts in order to descend below the level of the traditional knowledge contained at the level of the "leaves" (pages containing the concepts); 2)the hot words and a glossary in order to find the meaning of the most important terms; 3) the pull down menus to create personalised paths of teaching , on the part of the Teacher (the Teacher mode), and to create personalised paths of learning, on the part of the Student (the Student mode) (Norman1991). In fact , according to these last pull down menus, the Teacher may choose , after a previous definition, a given path to teach his concepts within a given lesson, and each Student may define one or more learning paths for a re-visitation of his own previous learning processes within a given temporal stage of his own learning .

The prototypes constructed thus far allow a free definition of the learning paths on the part of the students. This opportunity involves the problem of the learning control embedded in the model : when and if to leave the control of the learning flow of events to the Student or to the model in use. At present, the student has a free opportunity to go into the depth of the concepts represented in the screen forms (leaves and nodes), he can make free choices to navigate through the screen forms etc. .

We must not forget that we are in the initial stages of the project. Only in a subsequent phase of it , when more empirical results coming from a more exhaustive application are at our disposition , will it be possible to "superimpose" on the model some structures or modules which might allow a given kind of control, a given kind of diagnosis about the level of the acquired knowledge, etc. It is this last approach that is followed by the ITS's (Intelligent Tutoring Systems) in which we find the tutorial module, the diagnosis module, etc. It seems to us possible to implement such a theory into the project under discussion (Polson, 1988).

Many principles of the HCI (Human Computer Interaction) have been discussed by the project team in order to define the guidelines and the standards to be respected during the process of the project: unambiguous commands, their simplicity, appropriate choice of the objects that are always to be on the screen and those that may be re-called through the pull down menus. We have also taken into account the ergonomic probiem and the cost-benefit analysis existing for the construction of an artifact of such a nature: the degree of analysis and length (in words) of each concept, total number of screen forms per book, etc. etc.

Conclusions

Finally, we would like to conclude with some considerations which justify, "so to speak", this kind of approach where it is the interest in the human being rather than the artificial element, which predominates or prevails.

It is interesting to devote some words to the "how's" the team has carried out the production of the prototype software. The prototype, we must not forget, is also a software product and the following considerations, even if briefly expressed, belong to the software engineering field. The traditional model, based on the traditional functional decomposition software methodologies, frequently used for the process of construction of software on a large scale, has been discarded. According to this last approach, each phase constitutes, strictly speaking, an input for the subsequent phase, and above all, the final user only interacts with the construction process in the last phases, playing the role of a true user. In contrast, according to our philosophy, which we might call "a more cognitive philosophy or a more human-being-centered philosophy", the user, i.e. the Teacher and the Student, is a central figure that has to interact, from the very beginning, with the prototypes that the project team is going to realise during the course of the production process. This approach is obviously allowed by the fact that the programming language has been object-oriented (Kim J. &Lerch F.J.,1992). We might truly assert that the engineering approach we have followed constitutes a mix of the "prototype approach" and the "incremental approach". In fact, as regards the first approach, the interaction with the user (the Teacher and the Student), has been carried on since the very beginning of the project phases, in that Teacher and Student are the central points of the project. According to the second approach, some special functions have been embedded in the prototypes since the first steps of the project and have been kept constant for the whole duration of the project itself.

When we deal with artifacts , we ought to keep in mind the "personal perspective" , that is the perspective of the user (both Learner and Teacher), and the "systemic perspective", that is the perspective of the total system.

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This last perspective puts together the artifact (the prototype), the user (Learner and Teacher) and the task or function (to learn). Certainly the Student and the Teacher who utilise the artifact will have a personal perspective where the cognition process may be enlarged or enhanced. The artifact in our case is specifically built for better learning . We agree, on the other hand, that the artifact may change the task and, principally, it may change the mode of teaching on the part of the Teacher and the mode of learning on the part of the Student.

According to a systemic perspective we may say that the artifact has changed or is going to change the functions of the user: for the Teacher new elements to be taught and new modes of teaching, and for the Student, above all, new questions that can be asked and new elements that may be learned. Finally, and this is certainly a straightforward "expectation", the artifact will create a new mode for distributing teaching and learning tasks within an educational organisation.

As a "last but not least" consideration, we would like to stress a very interesting aspect or feature of this research, i.e. its project nature where the boundaries of rationality (Simon, 1945) involved in the project team have played a central role for the development of the model itself. These boundaries, according to our thought, are a central theme of investigation for the success of this kind of projects.

The project team may be considered as a micro organisation or an organisational unit which carries out a particular task, and acts in order to reach a specific purpose or end (see the first part of this paper). Each member of this team has put into operation, within his/her job, a personal expertise about the knowledge domain of Finance to be taught and a personal expertise about the knowledge domain on the Hypercard environment. It has not been necessary, thanks to this human expertise, to have a tool for the Hypertext design, rather the key problem has been to spread the knowledge of standards of the Hypercard language (Hyper talk), to settle technical rules for the symbolic language of icons,buttons, etc. within the members of the team (see above with reference to the language used by the team). In contrast with this approach, we often see some strongly structured approaches to the hypertext development based on the authoring on a large scale.

Our impression therefore is that in this problem of CBL (Computer Based Learning) we have strong elements of influence of the contingent real environment. We have, that is, contingent realities where what is prevalent, as in our case, are the organisational needs, the needs to improve the communication among the members of the group, therefore to build standards for a non natural language that will be used for the "art" of design . A creative component of each member exists, which mixes with the pure rationality of the programming environment. This whole problem constitutes a "terra incognita" for an interesting scientific investigation.

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Szabo, M. & Loney, P. (1994). A survey of the development and use of computer-based interactive multimedia training among selected northern Alberta organizations. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 103-112). Nashville, Tennessee. Omni Press.

A SURVEY OF THE DEVELOPMENT AND USE OF COMPUTER BASED INTERACTIVE MULTIMEDIA TRAINING AMONG SELECTED NORTHERN ALBERTA ORGANIZATIONS

by

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ABSTRACT

The purpose of this study was to find out the extent to which computer-based interactive multimedia training (CBIMT) was developed or used by a select group of employers in Edmonton, Alberta, Canada.

In February 1992, members of the Alberta Society for Human Resource and Organizational Development (ASHROD) were surveyed about their employers' development and use of CBIMT. ASHROD is an association of training, and organizational development professionals.

Findings included the following:
- Twelve of the 44 respondent organizations developed CBIMT and 20 used it.
- Large organizations developed CBIMT to use and small organizations developed it to sell.
- Use of CBIMT varied as functions of both business activity and size or organization.

Findings are discussed in comparison to findings of other North American studies.

DEFINITIONS

Computer-based Interactive Multimedia Training (CBIMT)
CBIMT is the use of CBT and/or CBIVT training environments to encourage learning through active processing of information (as opposed to the passive reception of information). A variety of other media can be used, including text and graphics. As the term CBIMT is relatively new, it was not used in the questionnaire. The component terms, CBT and CBIVT were used instead as they were judged to have more widespread meaning among survey respondents.

Computer-based Training (CBT)
CBT is the use of computers to deliver training.

Computer-based Interactive Video Training (CBIVT)
CBIVT is the addition of video to Computer-based Training.
training system.

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REVIEW OF THE LITERATURE

Use of CBIMT in Canada

Reports in periodicals indicate widespread use of CBIMT by large Canadian corporations (e.g. Duchastel, 1989).

Two Canadian surveys included questions about CBIMT: a March 1989 survey of the use of computer-based technologies within Canadian service industries, (Communications Canada & Industry, Science and Technology Canada, 1990) and a 1990 Conference Board of Canada survey of training in Canada (Larson & Blue, 1990).

The Technologies in Services study showed that 17% of employers with fewer than 200 employees used Computer Assisted Education (CAE) while 28% of those with more than 200 employees used it. Use also varied by industry group (see Table 3). Overall, 22% of Canadian service industry employers used CAE (Communications Canada & Industry, Science and Technology Canada, 1990).

The Conference Board Survey showed use of various training technologies to be between 6 - 15% of employers with substantial increases in use expected (Larson & Blue, 1990).

Use of CBIMT in the United States

Several U.S. surveys have included questions about use of CBIMT. Perhaps the most useful are those which have been conducted by Training magazine. Training, a journal oriented to the training profession, has conducted a survey of employer sponsored training annually since 1983. Questions about CBIMT have been included in these surveys (Geber, 1989, 1991; Gordon, 1985, 1986, 1988; Lee, 1987). Use of CBIMT among Training magazine survey respondents has grown throughout the period, with the level of use highest among large employers but growth in use highest among smaller organizations (Graph 1). Use of interactive video, however, has shown little growth, stalled at the 30 - 35% level among large organizations and at about 15% among all respondent organizations.

Hirschbuhl surveyed large U.S. corporations about their use of CBT. He reported that between 1985 and 1987 there was considerable growth in the use of CBIMT. He also identified variations in level of use among industry groups (Table 3).

DEVELOPMENT OF CBIMT

Information about the development of CBIMT is scarce and difficult to compare. Of 11 large Canadian employers featured in periodical articles between 1984 and 1991 as users of CBIMT, 6 developed courseware in-house. In the 1990 Conference Board of Canada survey it was found that 8% of respondents used authoring systems (Larson & Blue, 1990). Hirschbuhl found that in 1987, 6% of courseware was developed in-house, 24% custom developed and 70% was vendor-supplied generic software.

THE STUDY

The purpose of the study was to determine the status of CBIMT among a selected group of Edmonton employers. Organizations represented among the membership of the Edmonton chapter of the Alberta Society for Human Resource and Organizational Development

Szabo, M. & Loney, P. (1994). A survey of the development and use of computer-based interactive multimedia training among selected northern Alberta organizations. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 103-112). Nashville, Tennessee: Omni Press.

(ASHROD) were surveyed. ASHROD is an association of training, and organizational development professionals.

Fifty six ASHROD members were sent questionnaires. Forty four responded, for a response rate of 79%. Respondent organizations included private, public and not-for-profit sector employers, and small organizations which developed and/or delivered training.

The Questionnaire

As well as demographic questions, the survey included questions asking:

1. The extent to which survey respondents were developing and/or using CBIMT.
2. Whether respondents planned to increase, maintain or decrease their development and/or use of CBIMT during the coming year.
3. What authoring software respondents were using.
4. What computer hardware survey respondents used.
5. The job categories and types of skills is CBIMT was used for.
6. The advantages and disadvantages of using CBIMT.

FINDINGS

Development of CBIMT

Twelve of the 44 organizations developed CBIMT (Table 1). There were two kinds of developers - large organizations that developed for internal use and small organizations that developed courses for sale to other organizations. One large organization developed CBIMT for both internal use and sale (Graph 2 & table 2).

Quest and Authorware were the most common authoring systems used by developers.

Use of CBIMT

Of the 44 responding organizations, 20 used CBIMT. Of uses, 9 organizations used both CBT and CBIVT. None, however, used CBIMT to deliver more than 20% of their training.

As shown in other North American studies, the largest organizations used CBIMT the most. However, over 35% of smaller organizations also used it (Table 3).

CBIMT use varied as a function of industrial sector. Organizations in the goods producing, financial, and transportation, utility and communication sectors used CBIMT the most. Those in the retail and wholesale trade, government, and education services sectors used it the least (Table 4).

What CBIMT Was Used to Teach

Both Computer Based Training and Computer Based Interactive Video were used most to teach people how to use computer programs. As well as computer training CBT was used most to teach "hard" skills such as equipment operation and product knowledge. CBIVT, on the other hand, was also used to teach communication skills. That may be because video is often used to teach "soft" skills and video is a component of CBIVT.

Who Was trained Using CBIMT

In keeping with the differences in content taught, CBT was used most to train professional staff, technical staff and office/administrative support while CBIVT was used to train technical staff, managers and supervisors.

Equipment Used to Deliver CBIMT

IBM and IBM compatible were the computers used most frequently to deliver CBIMT. Macintoshes and Amigas were used in a minority of cases.

Advantages and Disadvantages of CBIMT

Flexibility and individualization were considered to be the greatest advantages of CBIMT and cost and availability of courseware the greatest disadvantages.

Expectations of Future Development or Use

Most developers and users expected to maintain or increase development and/or use of CBIMT. This suggests a high level of satisfaction.

Among the 22 non-users, only 2 were expected to implement CBIMT in the coming year while 6 were expected to investigate it.

SUMMARY

Among ASHROD members, there is a substantial amount of both development and use of CBIMT. One of the more interesting findings is that there are several small, independent, and locally based companies developing CBIMT for sale. The other is simply that there is this much involvement with CBIMT in Edmonton.

The study suggests several further questions.

1. To what extent does information about organizations represented among the ASHROD membership apply to all Edmonton employers? Considering the encouraging results of this study, a study of a more representative group of Edmonton employers would be interesting.
2. Do companies that develop CBIMT for sale tend to be small, independent, and locally based companies everywhere? Can we expect larger multi-branch and even multinational companies to take over this market or do smaller innovative companies have inherent advantages?
3. Will the development and use of CBIMT among ASHROD organizations and among Edmonton employers in general grow?
4. How will the introduction of new multimedia technologies such as digital video affect the development and use of CBIMT?

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Table 1

Development of CBIMT by Respondent Organizations

CBIMT Development	Count	Count Percent
CBT but not CBIVT....................	7	15.9%
both CBT and CBIVT....................	5	11.4%
Neither CBT nor CBIVT.................	32	72.7%
Total Cases...........................	44	100.0%

Table 2

CBIMT Development as a Function of Number of Employee

Number of Employees in North America	Development of CBIMT			Total Cases
	CBT but not CBIVT	both CBT and CBIVT	Neither CBT nor CBIVT	
Over 1000...........	4	1	19	24
500 - 999...........			3	3
250 - 499...........			2	2
100 - 249...........	2	1	3	6
50 - 99.............			1	1
Under 50............	1	3	3	7
Total Cases.........	7	5	31	43

Table 3

Use of CBIMT by Industry Group

Level of Use	Hirschbuhl Study	Technologies in Services	Ashrod Study
Highest	· Airlines · Data Processing · Banks · Insurance · Manufacturing	· Communication · Finance & Insurance	· Manufacturing & Resource · Financial, Banking, Insurance & Real est. · Business Services · Trans. Utilities & Comm.
Medium	· Telephone · Health	· Transportation · Wholesale Trade · Business Services	· Retail & Wholesale trade · Health & Medical
Lowest	· Accounting	· Retail Trade · Real Estate · Accomod. & Food	· Government · Education Services

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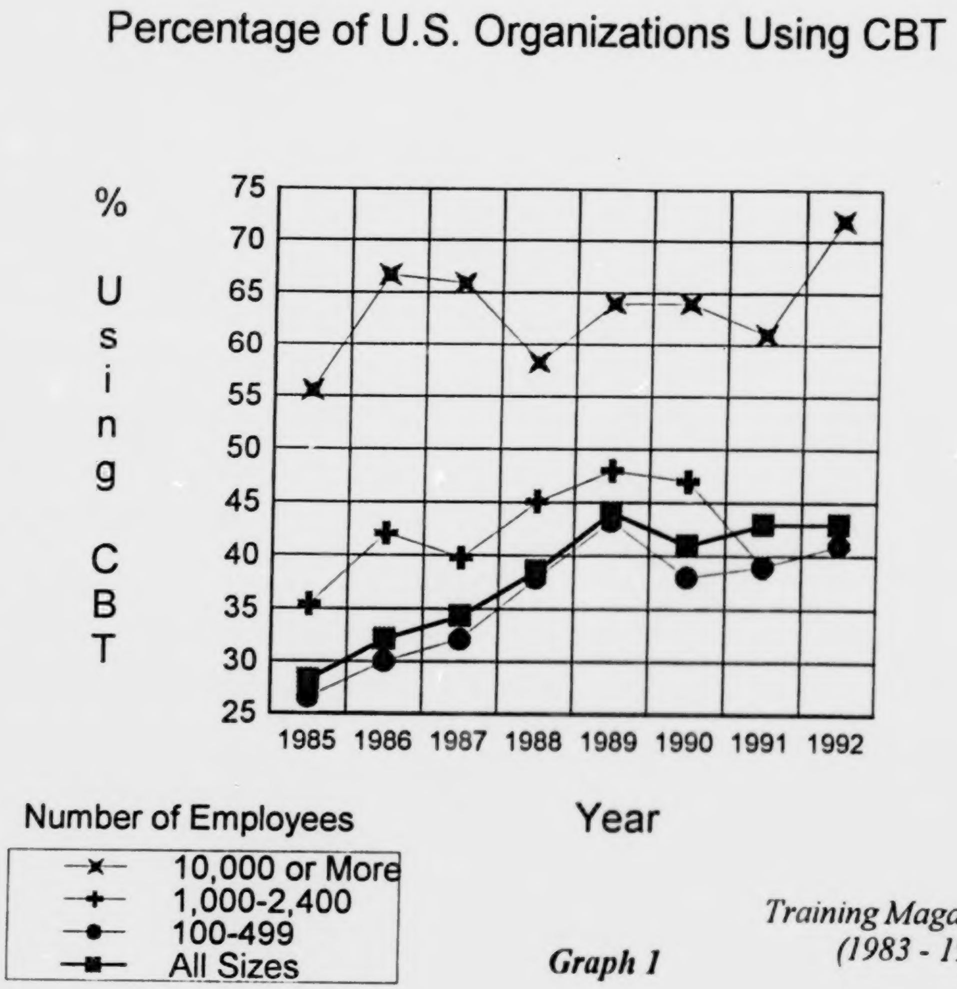
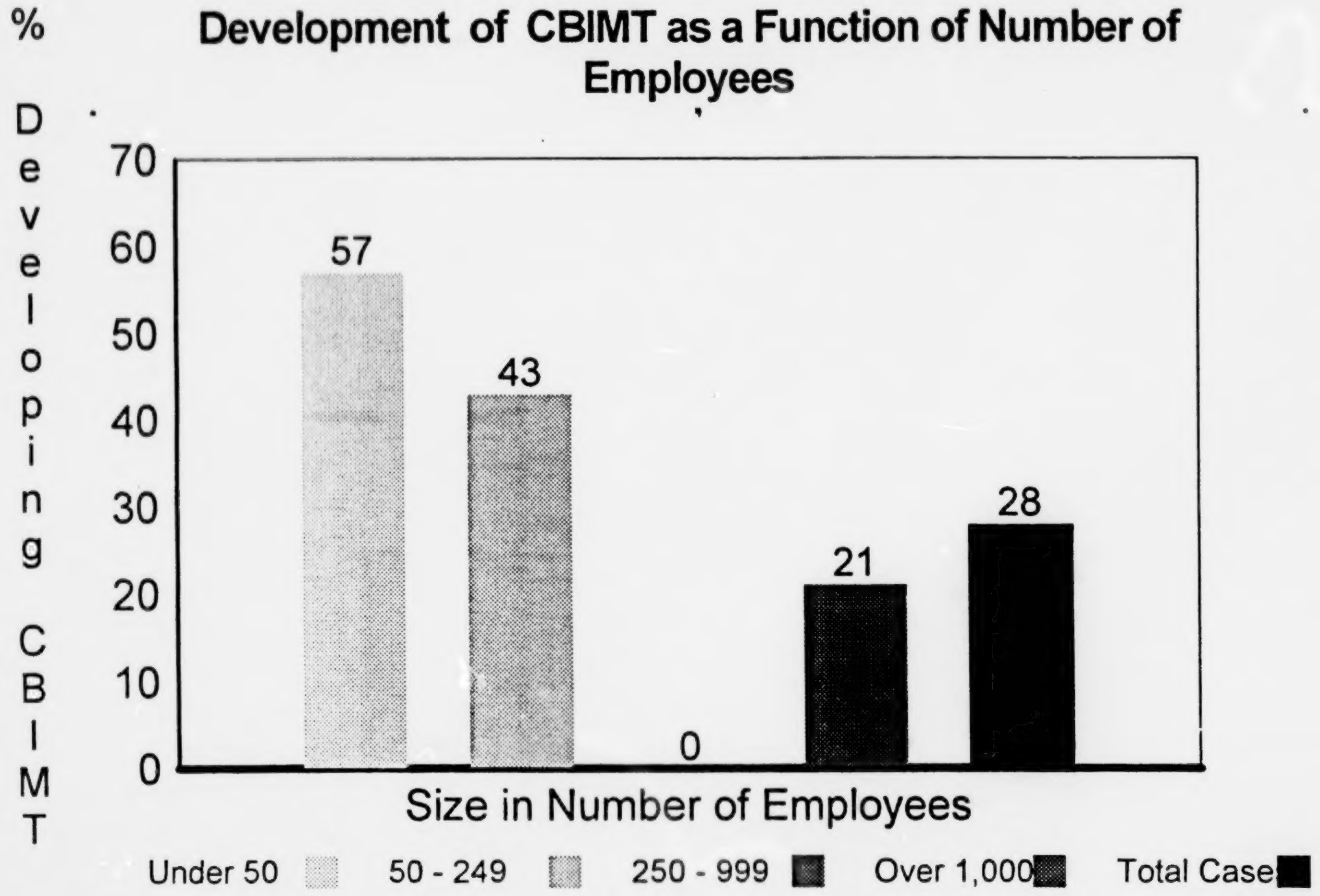


Graph 1

Training Magazine
(1983 - 1992)



Graph 2

Loney (1993)

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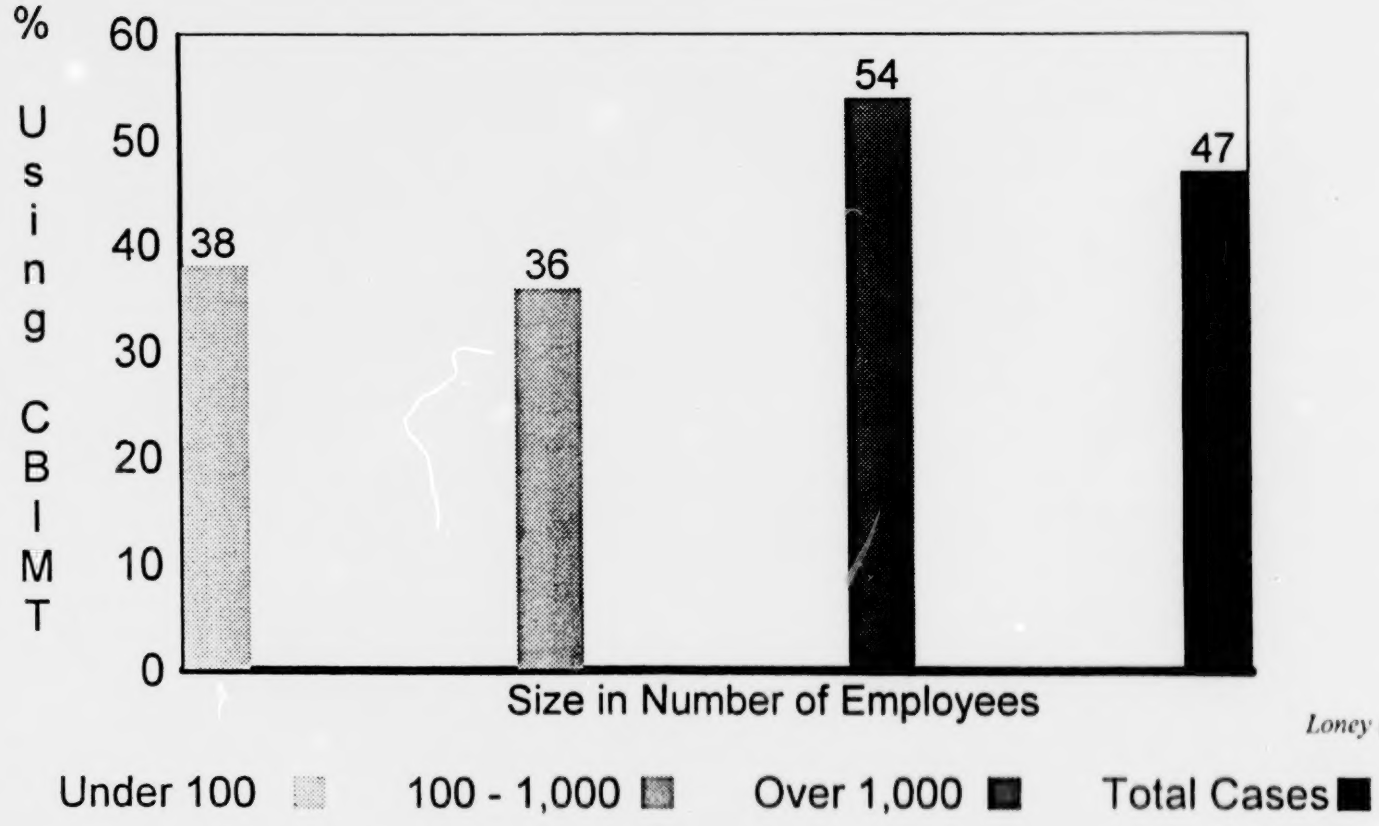
Use of CBIMT as a Function of Number of Employees



Loney (1993)

Graph 3

Szabo, M. & Loney, P. (1994). A survey of the development and use of computer-based interactive multimedia training among selected northern Alberta organizations. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 103-112). Nashville, Tennessee: Omni Press.

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MULTIMEDIA--A Makeover

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Abstract: How do you slow down the technological aging process? How do you restore to vigor a program whose aging body has run out of steam? In short, how do you make it young and sexy again? When your program is instructionally sound but the body and face start to go, it is time for a makeover. Back in the 1980s, the Department of Defense put together a team to showcase the potential of interactive video technology in foreign language instruction. The effort lasted several years and the product is as popular among learners today as it was back then. But as technology has continued to evolve, the older and sometimes proprietary hardware has begun to show its wrinkles. This paper will describe the restoration process and its results.

Introduction

In 1992 DoD contracted with Loral Western Development Labs to rework two foreign language interactive video (IAV) programs, in Spanish and Hebrew. This paper will concentrate on the Hebrew effort.

The hardware in the original program consisted of a Zenith 248 AT, a Pioneer 2000 video disk player, and a proprietary random access audio device known as Instavox. The authoring tools were Courseware Design System (CDS) and Courseware Design Language (CDL), used for fine tuning. Track two of the video disk was used for the MCEA (More Carefully Enunciated Audio); the Instavox 14" "flappy" contained idiomatic expressions, culture notes and an advanced level total comprehension listening test.

The audio quality of the Instavox left a lot to be desired, and its specialized cable made widespread dissemination of the courseware impossible. However, at the time, this was the only random access audio device that could fulfill our IAV/CAI development needs.

The new system consists of a 486 multimedia PC platform containing a 19" multisync monitor, 660MB hard drive, CD-ROM drive, SVGA card, video overlay card, digital audio card, videodisc player, audio mixer, amplifier, speakers and mouse. A motherboard with a clock doubling chip was added later to accelerate system response. In addition, a 90MB Bernoulli drive to facilitate data transfers between networks and an HP Laserjet IIIsi printer are provided for each of the two network locations.

The software falls into two categories: Vendor-supplied and Loral-developed. The actual coding was done in Authorware Professional for Windows 1.0, with a later upgrade to the 2.0 version. The Hadar Hebrew font selected for the conversion process did not project very well in certain point sizes until Loral modified it through the use of Fontographer, an applications tool. Loral also developed other applications, such as a record keeping tool, which follows the learner's path through the various complex layers of courseware, monitoring and keeping track of progress. More about this later.

The Learning Theory

Very early in the analysis phase of the original program, the Subject Matter Expert (SME) designer came upon a macrolevel strategy and structure for the development of instructional design by Reigeluth (1979, 1980, 1982, 1983) called Elaboration Theory.

Consider Gagne's conditions of learning. Gagne (1984) advocates that instruction be based on prerequisite knowledge, and, as a result, concepts must be taught first, then rules and principles, followed by problem solving at the application level. Elaboration theory, by contrast, starts with the overall picture (without much detail), elaborating from there as needed. One may start with a very simple elaboration, epitomizing (presenting the essential features), then summarizing and synthesizing before going one level deeper, to the next elaboration.

The strength of elaboration theory is precisely in this macrolevel approach. In most conventional courseware the learner is exposed to only a part of the overall structure at any given time. In elaboration theory the smaller parts are always related to the larger view, which procedure seems to increase the ability to learn concepts, promoting better transfer of information and enhancing long term retention. Like Norman's Web theory, Reigeluth's elaboration theory also holds that "memory is a network of ideas interrelated horizontally and vertically to the whole."

The Course

The product itself, an intermediate colloquial Hebrew language course, is based on a Laser disc containing two 30-minute situation comedies from the Israeli TV series Close Relatives. Side A, "The Maid," contains approximately 160 hours of instruction revolving around the controversial issue of hiring an Israeli Arab student to help with housework.

Typically, the constraints of normal platform instruction make it very difficult to address different learning styles and degrees of readiness. However, the elaboration theory approach lends itself very well to the needs of a wide population of learners.

After a thorough content analysis based on the fundamentals of elaboration theory (Jonassen, 1989), the overall structure was arranged in a top-down fashion. Principles, concepts and a few procedures were identified and sequenced accordingly.

There are three distinct entry levels in the course: Film, Scene, and Clip levels, each capable of interrelating with the other or standing on its own. Film level covers the entire 30-minutes of video, together with related learning materials and overall testing. The Film level material was divided into seven contextually meaningful portions (Scenes) which constitute one layer of elaboration. Each scene is composed of about four minutes of video with related learning aids and appropriate tests. Finally, each Scene was divided further into as many contextual video bites (Clips) as possible. A typical scene might contain as many as five Clips or as few as two. These range from between thirty seconds to two minutes of video and are packed with valuable information, practice and remediation, putting the learner in complete control of path and pace. There are no tests at this level.

Even though a few, strong learners may wish to enter the course at Film level and proceed very rapidly through it, most students will opt to view the entire video at Film level first, and then proceed down to the scene/clip levels, returning to the Film level once again at the end, to take the final examination.

This three-level division, with the top layer at each level synthesizing the elaborations connected to it, is reminiscent of Reigeluth's "zoom lens in a camera" approach; i.e., we always begin with the wide angle view and zoom in very gradually, summarizing and synthesizing as we move along. Within each of the above levels, prerequisites precede more complex structures,

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becoming the foundation for new learning and the glue for cumulative learning. The student is given ample opportunity for practice at each level. These elaborations become denser at the lowest level of instruction in order to build a strong foundation for the weaker learner. Throughout, the learner is able to control the mode and pace of instruction.

At Scene and Film levels, there are test item banks, that allow the computer to scramble the items before each new attempt. All practice materials are geared to the tests. The learner is allowed only one try per each test item, with instant remediation provided for every wrong reply. And last but not least, while the clip level materials are geared to the slow or average learner, to challenge the stronger student, there is an optional advanced level total comprehension graded aural exercise in rapid-fire Hebrew. It is presented in dialog format between two speakers and raises the course level to 3+.

"Mediated" learner control is the overall philosophy. The learner has full control over the sequence of learning, however, CMI (Computer Managed Instruction) steps in to guide and alert him/her (via a diagnostic examination) as to what segments or lessons need additional reviewing prior to taking the final test. This built-in "advisor", based on data collected by the record-keeping tool, sets the learner on the proper learning path, making the learning process more focused and efficient.

With every item of the video sound track analyzable down to the individual utterance, with culture and idiom notes, with tutorials on almost every aspect of the grammar and with exercises to reinforce every point related to content, the program provides challenge and remediation for every type of learner, while preparing all to pass the comprehensive Film-level final examination.

Conversion Preliminaries and Course Strategy

Since the design of the original course material is still valid, the conversion effort dealt primarily with hardware and screen design issues. The original DoD SME teamed up with the contractor to make sure that the change of face did not inadvertently modify the course design, and to assist with target language issues, such as quality assurance.

A series of meetings between the Government and Loral representatives preceded the actual conversion process. By September of 1992 the parties came to the following terms regarding the implementation strategy (1992):

® There would be a "maintainable interface" between the system (DOS/Windows) and the language enrichment materials; i.e., the government would be able, on its own, to later add to or modify the final product.
® The original instructional materials would be preserved; in the new hardware setup the major apparent change would be the replacement of the Instavox proprietary 14" random access audio device with a Windows-standard audio card.
® The original screen design would be modified and updated to give the product a complete facelift.
® The text and graphics would be similar to the original presentation, but updated to their new environment.
® Screen prints from the original course would be used to transfer the content to its new environment, and for documentation purposes.
® Student registration into the courseware would be via floppy disk, making it possible for the system to associate the user with data on his/her use of the enrichment materials.
® Student paths through the course and test item data analysis and evaluation would be developed as a separate module, to facilitate its use on any Windows-based machine.

- Record keeping data would be written to floppy diskette. Only the enrichment materials would reside on the hard drive.
- During the development phase, audio and video reference numbers, authoring models and screen printouts would ensure consistency of the final product.
- That final product would also include a student guide and course administrator's handbook. The former would deal with all information necessary for accessing the course, and the latter, with course registration and record-keeping.
- Movement through the course would be via the keyboard and mouse.

The Conversion Process

The actual development phase of the conversion began when Loral started identifying audio and video frame numbers and putting together pre-determined Models (pre-programmed templates) representative of the various portions of the courseware. While the coder concentrated on coding issues, the graphic designers worked closely with the original course designer/SME to modify the outward appearance of the course; i.e., the presentation screens.

The Government SME was on hand for consultation at all times, transcribing the cultural and idiom notes from Instavox, re-recording the transcribed notes and going over data files in order to eliminate typing errors before the materials were coded.

The SME review of the final product began shortly after the course started going on line. A standardized mechanism known as Technical Problem Reports (TPRs) was developed for the SME to communicate problems and their required fixes. As with any software review process, there were, ultimately, hundreds of corrections to be made. In general, the policy was that functional inconsistencies had to be dealt with right away; textual content and typographic errors would be left until coding was complete.

A weekly technical issues meeting was held between the Government SME and Loral's coder, minutes of which were presented at the general weekly meeting for TPR review and correction prioritization.

The Converted Course

The user interface allows learners full mobility among the various levels of instruction and from one activity to another no matter where they are. It is divided into four major areas: Level Selection area, Capability Selection area, Work area and Video/Audio Control area (Appendix 2).

After the title screen (Appendix 1), learners encounter the videodisk selection screen. Once the disc side has been confirmed, they enter one of three levels of instruction: Film, Scene or Clip (via MENU). These are displayed on the user interface screen in the *Level Selection* area. Course Reference and HELP also reside here and can be accessed at all times (Appendix 2).

The *Capability Selection* area is next (Appendix 2). It is preceded by the Title box which holds the address of the selection, reminding learners where they are. *The Capability Selection* area is equivalent to a menu, keeping the learners abreast of what selections are available. A muted icon is out of bounds for the duration of that activity. A selected icon is blue, indicating an activity which is in progress. By the same token, a blue-bordered work area indicates an ongoing activity.

Next comes the *Work Area.* (Appendix 3). The open half of the screen has been divided into four quadrants. The bottom right has been allocated to video only. The other three quadrants alternate among the various selections (from the Capability Selection area). No two activities can share a common work (screen) space simultaneously. A dialog box will alert the user of the need to close an open window prior to selecting another activity. Sub menu selections appear in the box blow the Capability Selection area as they become available.

Finally, there is a Video Control area, located across the bottom of the screen (Appendix 4). It contains a video locator bar whose color and appearance change, depending on the level the user is accessing. Its function, however, remains the same; i.e., to indicate what scene/clip is being viewed. The icons above the locator bar allow the learner the option of listening to an utterance over and over again, or playing a previous or next utterance at will. The *Video/Audio Control* area contains the VIDEO, SLOW AUDIO , AUDIO ONLY, AUDIO NOTES, and PAUSE icons. The AUDIO NOTES hold the entire content of the original INSTAVOX -- idiomatic expressions, culture notes and the audio track for the aural Advanced Total Comprehension graded exercise.

The only icon we have not mentioned is EXIT (Appendix 2). This icon is present no matter where in the course the user happens to be.

First time users are taken straight to the tutorial (HELP, Appendix 2) prior to commencing instruction to familiarize them with all the intricacies of this complex design. The tutorial introduces the course through explanatory text, allowing the selection of various areas of the screen to learn more about them. After completing the tutorial, the learner can begin the course.

The HELP (Appendix 2) icon allows the learner to review the tutorial or to display the Hebrew keyboard, leaving it on the screen as a reference for CLOZE and transcription exercises.

MENU (Appendix 2) takes the user to a graphic representation of the course. By selecting the various click/touch areas on the title bar, the learner can see a summary of a particular scene, preview the video, or make Scene/Clip level selections (Appendix 5).

At Film level the learner can access video, video with cultural and idiomatic expressions, word banks, a final examination, and the advanced-level listening comprehension graded exercise.

Scene level provides all of the above plus various word reviews and a diagnostic and final (Scene level) examination.

At Clip level the learner can have video, keywords, idiom notes, culture notes, a transcript of the text, an accompanying English translation, transcript-associated keywords, idioms, culture notes, specialized vocabulary notes and a three-level grammar review and practice. Every clip also contains comprehension exercises.

Although each learning event or activity has a distinct window design, there are some common characteristics among the various windows: The title bar contains the title and topic of an activity from the Capability Selection area. It may also show the number of attempts per item, provide hints, directions, videodisk availability, plot, characters, English/Hebrew translations, grammar notes, exercises and various word review games.

Conclusions

The coding and pilot testing were completed in November of 1993. The course will be ready for distribution and field testing as soon as final revisions are made.

The existing (old) version of the course has been in continuous use since 1988, and, even with the dated, clumsy interface, jerry-rigged hardware and clunky processor, continues to be highly popular with our students. If the updated version is even half as successful, we can expect many more years of useful life. Makeovers, of course, cannot work miracles; there has to be underlying substance to work on, in this case, solid instructional design.

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Cowen, M.B. (1994). Interactive hypermedia for training electronic surveillance personnel. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 119-123). Nashville, Tennessee: Omni Press.

Interactive Hypermedia For Training Electronic Surveillance Personnel

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Abstract: The cognitive goal of naval electronic surveillance personnel is to match intercepted signal parameters with the names of specific emitters and their associated platforms. It was hypothesized that an instructional hypermedia-based training system will improve the electronic surveillance technician's ability to classify emitters. The training system provides opportunities for the technician to interact with a simulation of the electronic surveillance environment. A graphic representation of the console of the electronic surveillance device was presented to the technician. The training procedure consisted of hooking an emitter symbol and selecting various multi-media representations of the emitter including sound, text, digitized photographs, and animated graphics. Emitter classification training was administered to 48 subjects using either instructional hypermedia or a printed listing. The training using the instructional hypermedia was found to be more effective than the training using the printed listings.

Background and Problem

On most US. Navy ships electronic warfare (EW) specialists operate electronic surveillance devices to detect and intercept radar signals. The cognitive goal of naval electronic surveillance personnel is to match intercepted signal parameters with the names of specific emitters (e.g., radars, missiles) and their associated platforms (e.g., ships, aircraft). The electronic surveillance technician searching for emissions must be trained as if the electronic surveillance devices had no automatic identification capability. The electronic surveillance technician must rely solely on intercepted signal parameters as the starting point for emitter classification and identification.

Objective

The objective of this project was to design, develop and test a training intervention to improve the electronic surveillance technician's ability to classify emitters.

Instructional Hypermedia

Although introducing technology into the training environment does not necessarily enhance learning (Clark, 1983), incorporating hypermedia (Conklin, 1987) into an instructional delivery system may increase the effectiveness of Navy training. A hypermedia system is a computerized database consisting of text, graphic, video, and sound. The database consists of a system of nodes and links. Nodes store a quantity of information. Users navigate through the system of nodes via links. The hypermedia system creates a structuring of the data or a knowledge base. Hypermedia may create an effective learning environment because users actively associate knowledge when searching paths and retrieving information (Anderson, 1988).

It is hypothesized that an instructional hypermedia-based training system will improve the EW specialist's ability to classify emitters. The proposed training provides opportunities for the technician to interact with a simulation of the electronic surveillance environment. The training is self-paced and under learner control. A graphic representation of the electronic surveillance device console displaying numerous emitter symbols is presented to the technician. The training procedure consists of hooking a symbol and selecting various multi-media representations of the emitter including sound, text, digitized photographs, and animated graphics which enables the technician to link digital parameters to concrete images of radars, platforms, and weapon systems. The technician can hook more than one emitter so that representations can be compared and contrasted. This

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[1] The opinions expressed in this paper are those of the author, are not official, and do not necessarily reflect the views of the Navy Department.

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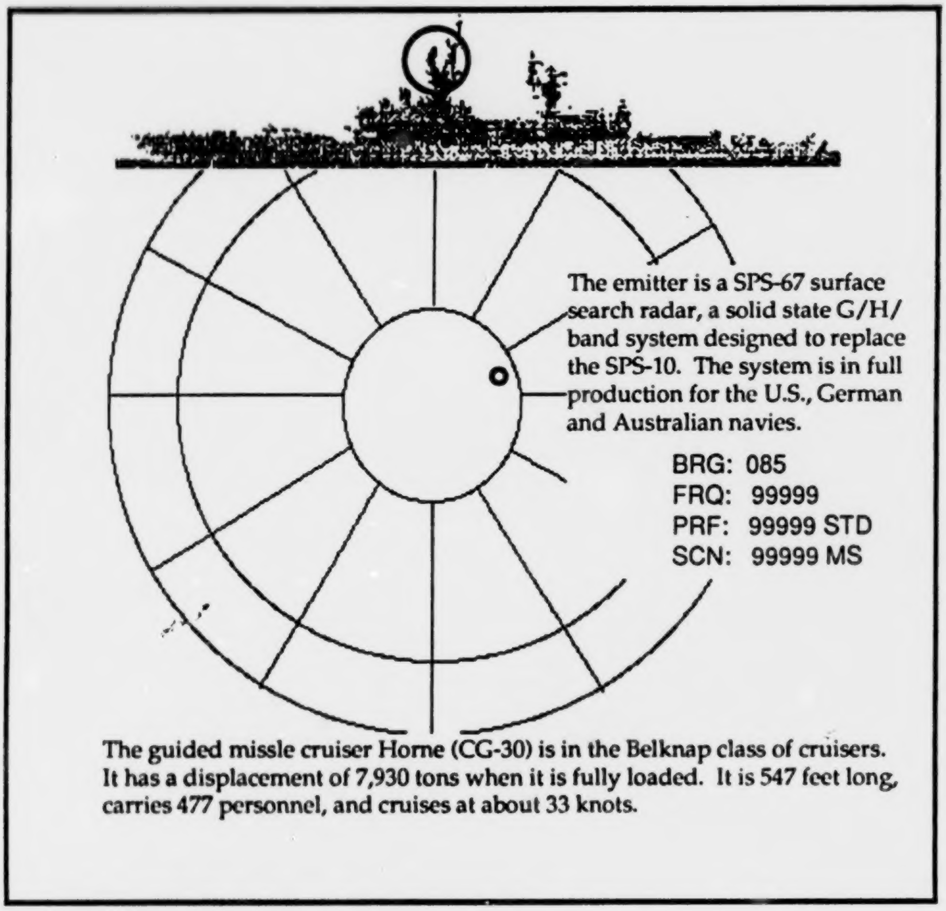
approach will help the techician identify emitters and their respective platforms because interactions with the instructional hypermedia will create elaborate cognitive structures (Reigeluth & Stein, 1983) of the emitter data bases.

A computer-based lesson incorporating the instructional hypermedia approach was developed for a database of 35 emitters. The instructional hypermedia was tested in two phases. Experiment I tested for immediate recall of the to-be-learned material and Experiment II tested for recall of the to-be-learned material immediately and two days after the intervention, and included a cooperative learning treatment group.



The emitter is a SPS-67 surface search radar, a solid state G/H/ band system designed to replace the SPS-10. The system is in full production for the U.S., German and Australian navies.

BRG: 085
FRQ: 99999
PRF: 99999 STD
SCN: 99999 MS

The guided missle cruiser Horne (CG-30) is in the Belknap class of cruisers. It has a displacement of 7,930 tons when it is fully loaded. It is 547 feet long, carries 477 personnel, and cruises at about 33 knots.

Figure 1. An Instructional Hypermedia Display

Method

Treatment Group

Treatment group subjects received a computer-based emitter classification lesson incorporating the instructional hypermedia. The lesson consists of two parts: Freeplay and Drill. The Freeplay displays the electronic surveillance devices's console to the user. An example of emitters displayed on the "wagon wheel" of the electronic surveillance device during Freeplay is sketched in figure 1. During Freeplay, the subject clicks on emitter symbols using a mouse and then selects sound, picture, animated graphic, and textual representations of the emitter. During Drill, the user practices associating emitter parameters with radars and platforms. For the emitter parameters displayed, the user selects the correct radar and platform. Feedback is provided for every response. The treatment lasted about 25 minutes.

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Control Group

Control group subjects received an alternative emitter classification lesson that resembles training that might be provided prior to a warfare exercise. Subjects were required to learn the emitter data base from a printed listing. The data are in notebook form and resembles an Electronic Order of Battle. The control training lasted about 15 minutes.

The subjects in both groups were administered a test prior to and after the intervention. The test contains 64 multiple choice items that are presented randomly; 35 items require the subject to identify the correct radar when given the emitter parameters; 29 items require the subject to identify the correct platform when given the radar.

Experiment I. This experiment consisted of two sessions, two weeks apart. During the first session, the subjects were administered the multiple choice test. During the second session, the subjects received the hypermedia or control training, immediately followed by the multiple choice test

Experiment II. This experiment consisted of two sessions, two days apart. During the first session, the subjects were administered the multiple choice test, the hypermedia or control training, and the multiple choice test again. During the second session, the subjects received the multiple choice test.

During experiment I, most of the subjects during the hypermedia training made specific comments about the emitters and associated multimedia representations to the experimenter. They wanted to provide some extraneous information about the displayed emitters. For example, "I saw that radar on a destroyer last year in the Persian Gulf" and "That radar is very similar to the radar aboard my ship" were said to the experimenter. This reaction to the hypermedia should have been expected because much of the training for electronic surveillance devices is provided in the operational environment (i.e., on the job). In this environment the EW technician must successfully interact with other surveillance personnel as well as the other combat information center personnel. Consequently, the hypermedia training intervention was tested in a cooperative learning setting (i.e., a cooperative learning treatment group) in experiment II. It is believed that subjects working together will recall and synthesize more information than they could working alone (Webb, 1990).

Subjects in the cooperative learning group were individually pre-tested and then randomly subdivided into pairs. The hypermedia training was administered to the pairs, but the subjects received the post-tests individually. It was predicted that the treatment group and the cooperative learning treatment group would significantly outperform the control group on the post-intervention tests.

Results

Twenty subjects were tested for experiment I and 28 were tested for experiment II. For experiment I, data was analyzed for 10 treatment subjects and 7 control subjects. Two experiment I subjects did not return for the second session and one experiment I subject's data were lost due to a computer malfunction. For experiment II, data was analyzed for 8 treatment subjects, 9 cooperative learning subjects, and 8 control subjects. Three experiment I subjects did not return for the second session.

Experiment I. Mean test score by training group is shown in figure 2.. After training, the treatment group's score increased about 18% ($t(9) = 6.39, p < .001$) while the control group's score increased about 7% ($t(6) = 11.21, p < .001$). The treatment group's performance gain was significantly higher than the control group's performance gain ($F(1,14) = 15.73, p < .001$).

Experiment II. Mean test score by training group is shown in Figure 3. Immediately after training, the treatment group's score increased about 20% ($t(7) = 6.86, p < .001$), cooperative learning increased about 13% ($t(8) = 4.61, p < .01$), and the control group's score increased about 7% ($t(7) = 3.10, p < .05$). The treatment group's immediate performance gain was significantly higher than the control group's immediate performance gain ($F(1,13) = 13.20, p < .01$). Although the cooperative learning group's immediate performance gain was higher than the control group's immediate performance gain, the difference was not statistically significant.

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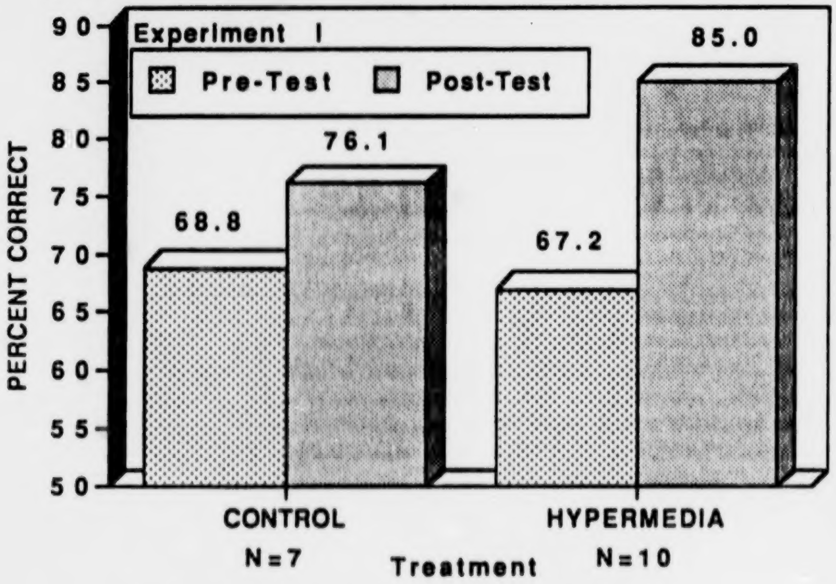

Figure 2. Mean Performance by Training Group (Experiment I).

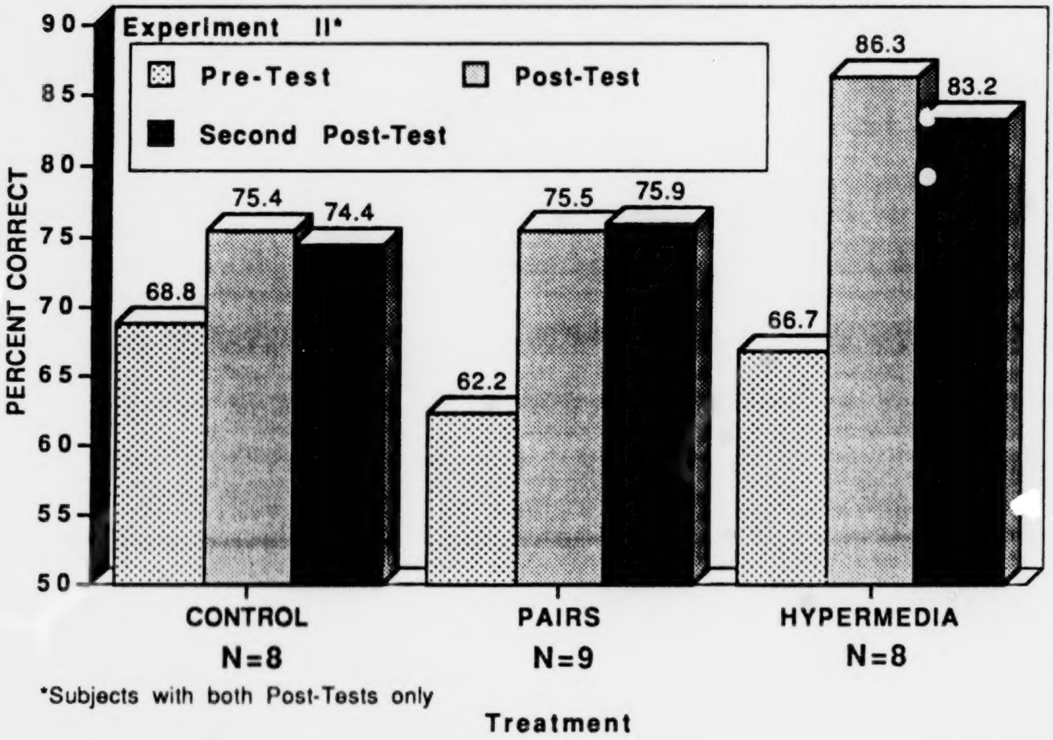

Figure 3. Mean Performance By Training Group (Experiment II).

Each group's performance declined little two days after training. When compared to the pretest score, the treatment group's score increased about 17% ($t(7) = 8.04$, $p < .001$), cooperative learning group's score increased about 14% ($t(8) = 4.33$, $p < .01$), and the control group's score increased about 6% ($t(7) = 2.44$, $p < .05$). Again, the treatment group's performance gain was significantly higher than the control group's performance gain ($F(1,13) = 11.49$, $p < .01$). The cooperative learning group's performance gain was higher than the control group's performance gain, but this difference was not statistically significant.

Discussion

In this study training was developed to improve the EW specialist's ability to classify emitters. Two training modules were developed: One using an instructional hypermedia approach (the treatment) and the other using a traditional approach (the control). Subjects were trained using instructional hypermedia in pairs and alone. Subjects were tested prior to, immediately after, and two days after training. Technician performance improved significantly for both hypermedia and control groups even two days after training. The hypermedia was effective for training subjects in pairs or individually.

It was hypothesized that emitter classification training employing instructional hypermedia would be more effective than training using a printed listing. Training using instructional hypermedia was found to be significantly more effective than training using print only when provided to individuals working alone . Results using instructional hypermedia in a cooperative setting were promising, but need to be to supported with future research. Previous investigations of computerized instruction in academic settings have found that performance improved when students were paired (Dalton, 1990; Stephenson, 1992). Cooperative pairs of students were better able to reorganize and clarify, guide and correct, and build on each other's ideas. Students working in cooperative learning environments have been found to have reduced anxiety, an increased willingness to ask for help, and an increased willingness to take feedback seriously than students working alone. A closer examination of the effects of instructional hypermedia in cooperative settings is needed.

Hypermedia technology is becoming widespread and is a suitable candidate for delivering emitter classification training. In response to post-training questions, all subjects in the treatment groups thought that the instructional hypermedia helped their performance and should be implemented. The instructional hypermedia was found to be easier to use ($t(32) = 2.11$, $p < .05$) and more enjoyable ($t(30) = 3.43$, $p < .002$) than the control training. Moreover, when given a choice of training, all control subjects who were shown the treatment (after the post-test) preferred the instructional hypermedia over the control training.

Our investigation provides evidence for using instructional hypermedia for training electronic surveillance personnel to classify emitters. In addition to validating an instructional technology approach, a considerable step was made toward designing a practical system for training. Therefore, with appropriate attention to implementation, this computer-based instructional system will impact naval electronic surveillance.

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A Large Scale Evaluation of a Hypermedia Intelligent Tutoring System

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Abstract

This paper presents the results of an experimental evaluation of the Mobile Subscriber Remote-telephone Terminal (MSRT) Tutor (the MSRT is a mobile phone that the Army uses, but whose operation is much more difficult than the commercial equivalent). The evaluation was conducted in the regular training environment used for communications training in the U.S. Army. Soldiers who were required to know how to operate the MSRT, but had not yet learned, were used as participants in this study. Two treatments were compared. The computer-based tutor was "pitted" against a treatment that had the participants operate the actual equipment. We assumed this "hands-on" approach would be superior to the computer tutor. The test was to perform the operations procedures on the actual equipment. Accuracy and time were measured. Results indicate that both groups are equally accurate, but the hands-on group was able to perform the procedures more quickly. We conclude by recommending the computer-based tutor because of the prohibitive costs associated with hands-on training.

The first Intelligent Tutoring System (ITS) was built over twenty years ago (Carbonell, 1970). Since then, much work has been done in the area designing more "intelligent" systems by improving student, expert, and pedagogical modeling (see, for example, the special issue on student modeling in the Journal of Artificial Intelligence in Education (McCalla & Greer, 1993) for a series of articles on this advancement). However, very little effort has been done in the area of evaluating the effectiveness of ITS. In fact, one of the major criticisms of this field of inquiry is the lack of evaluation data (Rosenberg, 1987). Some have suggested plans for evaluation (Littman & Soloway, 1988; Shute & Regian, 1993), while others have begun the process of conducting evaluation (Anderson, Boyle, & Reiser, 1985; Corbett & Anderson, 1991; Shute & Gawlick-Grendell, 1993; Shute & Glaser, 1990). The results of this evidence are that estimates of effectiveness based on Bloom's (1984) 2-sigma problem place ITS at about a 1.0 effect size (Legree & Gillis, 1991; Legree, Gillis, & Orey, 1993). However, this estimate is based on a limited number of studies that have some limitations. The intent of this paper is to add to this evidence by reporting the results of a field-based evaluation.

Background

Legree and Gillis (1991) have done an extensive review of evaluations that have been conducted. They distinguish between extensive and minimal evaluation. Those evaluations that have had a long enough treatment have produced the 1.0 effect size. Those that have not been large scale systems have not produced the 1.0 effect size. Of the studies that they reviewed that had the 1.0 effect size, one is difficult to fully understand (Anderson, et al., 1985). Anderson, et al.'s, study has been cited frequently for its impact of tutoring, yet it does not include details of the experiment (it was published in a popular computing magazine, not an experimental professional journal). That leaves only a very few extensive, well-designed studies that are used to account for the effect size of ITS.

Shute and Regian (1993) intimate that much research is underway at Armstrong Labs related to the effectiveness of ITS systems. These studies are well-controlled experimental studies that use "paid" participants to learn from their systems. These experiments are controlled very well and have great internal validity. However, these experiments have little or no external validity. In fact, Farquhar (1993) present the results of an experiment with a tutor that trains people to operate a loading crane through a simulated control panel. This crane and its simulated control panel do not exist. It is a tutor for experimental purposes only. These results need to be verified with real learners learning real things in the real world.

Shute and Regian refer to these real world examples as quasi-experimental studies because often they do not use random sampling and there is very little experimental control. They characterize a well-controlled experimental design that takes place in a real world setting with real learners who really need to know the content as "Research Utopia". This "Utopia" is the goal of the current effort.

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Method

Shute and Regian specify seven factors in designing a "good" evaluation. They are:

1. Delineate the goals of the tutor.
2. Define the goals of the evaluation study.
3. Select the appropriate design to meet the defined goals.
4. Instantiate the design with appropriate measures, number and type of subjects, and control conditions.
5. Make careful logistical preparations for conducting the study.
6. Pilot test the tutor and the study, and
7. Determine the primary data analyses as you plan the study (p. 249).

I will use these as a framework for explaining the methodology of this experiment.

Tutor Goals

First, you need to define the goals of the tutor. In this case, the tutor is designed to teach a learner how to operate a piece of Army communications equipment called the MSRT. It consists of three primary components. The first is something that is very much like a telephone except that it has programming elements for security purposes. This component is common in the Army communication network. The second component is the radio that has a variety of switches, knobs, buttons and lights. The last part of the equipment is the power supply that has a variety of switches. The goal of the tutor is to teach soldiers how to power up the equipment, load security information, link into the communication network, and finally, place a call. For a complete description of the MSRT Tutor, see Orey, Trent and Young (1993).

Study Goals

Second, you need to define the goals of the study. I want to know which is better -- the MSRT Tutor or the best available training (tutoring while operating the actual equipment). The MSRT Tutoring environment is a hypermedia simulation of the MSRT. I believe that it is better to train on the actual equipment. Unfortunately, to operate the MSRT, $5 million worth of equipment and eight switch operators need to be "on-line" in order to use the MSRT. In addition to the equipment, you still need to have someone or something provide the instruction. I chose to use tutors to guide the learner as they used the MSRT equipment. Although this is costly, I wanted to compare the MSRT Tutor to the best available instruction.

Experimental Design

Third, choose an experimental design to meet your goals. Using Shute and Regian's (1993) terms, I chose to use a summative, benchmark, "quasi-experimental" design. However, they sometimes use "quasi-experimental" to mean real-world and other times it means to use random sampling. Both of these are important experimental issues. The basic design takes place in the real world, but I attempt to use experimental principles. I begin by using a program in LinkWay Live! to randomly sample two groups. The design of this program is to create equivalent size groups. That is to say, the program asks for the size of the pool of subjects. It runs once by using the random number generator to place each person into one of two groups. At the end, if the size of the two groups is not equal (or off by one in the case of an odd number of subjects in the pool), it runs again until the groups are equal. The program prints a list of E's and C's (for experimental and control) which is then used in conjunction with an alphabetical list of participants for the assignments.

Design, Measures, and Subjects

Their fourth principle involves experimental logistics (appropriate measures, controls, sample sizes). I decided that the goal of the tutor was to teach someone to operate an MSRT, so the test ought to have the learner operate an MSRT. I use trained observers, a check list of steps, and a stop watch to measure their performance. The check list is used to generate a measure of accuracy while the stop watch is used to measure their speed. In order to have consistency between observers, I video taped a group of soldiers as they performed operation procedures on the MSRT equipment. These video tapes were edited into two tapes -- one for practice and one for calculating inter-rater reliabilities for the observers. These

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reliabilities were calculated using correlations between raters. The training and the inter-rater reliability data collection took eight hours.

The entire pool of participants from a class was used in the experiment. The experiment used 53 officers. Five allied officers were dismissed from the experiment because they had limited English fluency. The remaining 48 were randomly placed into one of two groups. This group of officers was new to the Army. This was their first assignment. The MSRT Tutor was designed to teach general users. The population that I had access to was Signal Corp soldiers. Although a Signal Corp soldier does not have exactly the same background as other general purpose users, many characteristics are shared. They all were required to know how to use the MSRT. The experiment used officers who had just entered the Army, therefore, there background knowledge of communcations equipment would be about the same as the general purpose user population.

Because the existing instruction included a one-hour lecture on a variety of aspects of the MSRT, I chose to have both groups receive this instruction. Further, both groups viewed a training video on MSRT operation prior to working with the separate treatments. Finally, both groups gathered around a single MSRT as its operation was demonstrated by the instructor. Each group received these common instructional treatments on the morning of their respective treatments. The same instructor and materials were used on both days. After these pre-treatments, the Computer group was turned loose on the Tutor and the Hands-on group came to the MSRTs in groups of six (one MSRT per learner). The "tutor" then guided the learners through the operation of the MSRT. In the case of the Hands-on group, once they had performed the operations procedures, they sat down and the next group came forward. Frequently, others would gather around the MSRTs and look on while a group of six was practicing the procedures. After all the groups had their hands-on experience, some came back to practice again. Once all were ready, the MSRTs were separated from the learners with a partition and small groups were "tested-out" on the procedures (I used 5 raters for the experiment).

The Computer group went through the tutor twice. The operations procedures had been broken down into six problems. The tutor used a gross measure for mastery (fewer than 4 errors and 4 coach assists). After mastering a problem, the tutor went on to the next. At the end, the students were asked to do the tutor again so that they "mastered" all six procedures twice. As soon as they completed the tutor, they could "test-out" on the actual MSRT.

The "test-out" had the learner come to the MSRT equipment with an observer standing next to the equipment observing the actions taken. A 2-page check list was created to be used as a guide to the observation. There were 47 separate steps on the check list. In the observer training, we decided which steps were considered potentially damaging to the equipment or were vital to operating the equipment and which could be left undone. There were 9 steps that could be left undone and the remaining ones were considered vital. If intervention was warranted, the observers were instructed to only state a vital step that appeared on the check list. No other assistance was provided. The observer could place a check (the learner successfully performed a step), a circle (the learner was told to perform a vital step), or a blank (the learner did not perform a non-critical step) next to each item in the check list. A composite score was created from this data. Providing assistance was deemed more damaging than not doing something (circles versus blanks). Therefore, we took the total number of steps and subtracted twice the number of circles and once the number of blanks, which is expressed like -- $(47-(2X\#ofCirlces)-\#ofBlanks)$. This figure was the accuracy figure. Speed was calculated in seconds.

The learner was asked to perform the procedures twice immediately following the learning phase of the experiment. The rationale for this was that the Computer group would necessarily need to transfer their knowledge from what became known as the "cartoon" version to the real equipment. I felt that these mappings could be made in the first attempt and then their performance ought to be the same as the hands-on group.

There were three side issues that were of concern in this effort. The first was to determine some more qualitative feedback about the learner's feelings about the instruction. A questionnaire with 12 items covering issues such as good use of graphics, overall value of the instruction, would you recommend to your peers, was developed for the experiment. In addition, I decided to explore the motivational aspects of the training using Keller's (1987) ARCS model of motivation. We used an instrument created by Chanlin (1993). Finally, I were interested in the differential effects of the treatment on decay. Therefore, I had the participants perform the operations procedures four weeks after the learning treatments.

Logistics

The fifth principle involves logistical preparations. This is truly the most difficult part of the "real world" experiment and the results show that this was somewhat limited. I randomly generated groups

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for the experiment and sent them to the instructional supervisor, but the subjects were placed into one of two groups based on the upper and lower half of an alphabetical list. The two groups were to receive the same lecture portion, but the instructor's materials had been mis-sequenced. As a result, he cut the Computer group's lecture in half. Therefore, the groups were not exactly randomly sampled and the groups did not receive exactly equivalent treatments. The result was that the design became "quasi" experimental. Perhaps Shute and Regian (1993) were correct when they characterized field research as quasi-experimental.

Pilot Test

Pilot test the study is the sixth principle. A pilot test was run and many experimental problems were resolved. This was vital, and perhaps two or more pilots ought to be conducted given our experience. The pilot test resulted in modifications to the Tutor as well as modifications to experimental procedures.

Data Analysis

Finally, Shute and Regian (1993) suggest that you plan the data analysis procedures. There are essentially five separate analyses that needed to be done in this experiment. The first was already discussed -- inter-rater reliabilities. A simple correlation matrix for the accuracy measure calculated from the values on the observation check list was used for inter-rater reliability. Because all evaluators evaluate the exact same person from the exact same perspective, this is a fairly accurate representation of the rating performance. In an earlier pre-pilot, we found that time was highly correlated, so we did not measure this. The results of the first experiment indicated that the evaluators needed further training that resulted in fairly consistent results in this experiment (See, Figures 1).

	R1	R2	R3	R4	R5
R1	1.000	.955	.909	.842	.895
R2	.955	1.000	.916	.888	.918
R3	.909	.916	1.000	.945	.931
R4	.842	.888	.945	1.000	.898
R5	.895	.918	.931	.898	1.000

9 observations were used in this

Figure 1. Inter-rater reliabilities for this experiment.

The second and third analysis procedure is essentially the same. This is the primary analysis for this experiment. These two analyses are the analyses of the two primarily dependent measures -- time and accuracy of performance. These measures are collected three times for each of the two groups. Therefore, a 2X3 ANOVA with three repeated measures was used. I was interested primarily in the main effect related to grouping, but I also had an interest in the main effect for repeated measures in as much as I were interested in the decay factor. I also had an interest in any interactions because it would imply that the groups' behavior differed at different data collection times. Post hoc tests would be t-tests on each individual interaction element and an ANOVA for the main effect of repeated measure.

The questionnaire was nominal data, so I used a chi-squared analysis to compare the groups. There were 12 items, so there were 12 separate chi-squared tests. The motivation instrument collapsed to four categories -- attention, relevance, confidence, and satisfaction. These composite scores were compared using a t-test for each (total of 4). An alpha level of 0.05 was used on all analyses.

Results and Discussion

We begin with the accuracy measures of performance. The results of the repeated measures ANOVA indicated that there was a main effect overall for the repeated measure ($F=65.16, p<0.001$). In the post hoc ANOVA using Fisher's PLSD, each time we measured their accuracy was different from each other. The best performance was the second time immediately following training ($\overline{X}=42.7$) followed by the test immediately following training ($\overline{X}=37.2$) and the worst was four weeks later ($\overline{X}=23.5$). Of particular interest to this discussion is the fact that there is this large decay in performance. In later versions of the tutor, this aspect will be explored. The fact that there were no main effects for the experimental groupings ($F=0.48, p=0.49$) was indeed heartening. After all, we were attempting to see how

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well the tutor stood up against the best possible alternative training. The fact that there were no interactions also was heartening (F=0.66, p=0.52). Refer to Figures 2 and 3 for details of this test.

Means Table for Perfs
Effect: Category for Perfs

	Count	Mean	Std. Dev.	Std. Err.
Perf.1	44	37.205	10.667	1.608
Perf.2	44	42.727	3.990	.602
Perf.3	44	23.500	12.409	1.871

Figure 2. Descriptive statistics for each accuracy of performance measure.

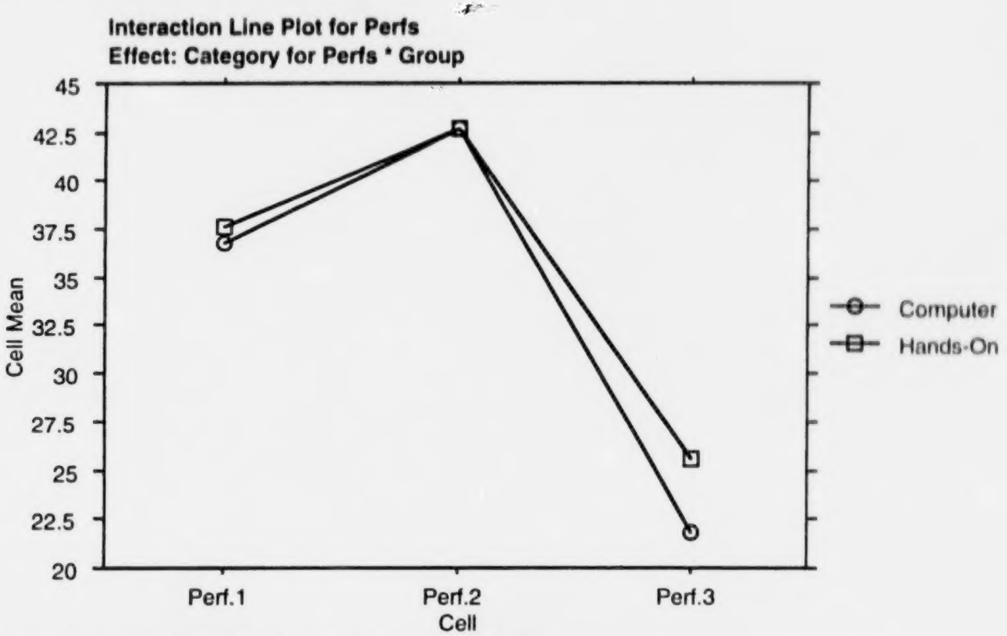

Figure 3. Interaction graph for the accuracy of performance measure.

The results of the repeated measures analysis for speed were less favorable for the tutor. There was a main effect for group (F=7.01, p=0.01). Referring to Figure 4, clearly the computer group took longer to perform the tasks than the hands-on group. In fact, if you examine the graph in Figure 5, you will notice that much of this difference was on the first and last tests (though there was no interaction, F=1.69, p=0.19). I had assumed that the speed of performance had become essentially equivalent after the second immediate test. However, the speed of performance of the computer group seemed to have slowed to the same performance speed as their initial transfer task speed. Perhaps, one could argue that they were again relying on a computer-based representation in memory and were attempting to make mappings again to the actual equipment. However, further data would need to be collected to verify this conjecture. It should be noted that these same results were obtained in the pilot (although the computer group was faster on the decay test than the first immediate test).

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Means Table for T-time
Effect: Group

	Count	Mean	Std. Dev.	Std. Err.
Computer	72	524.417	213.896	25.208
Hands-On	60	430.000	167.084	21.570

Figure 4. Descriptive statistics for time on performance.

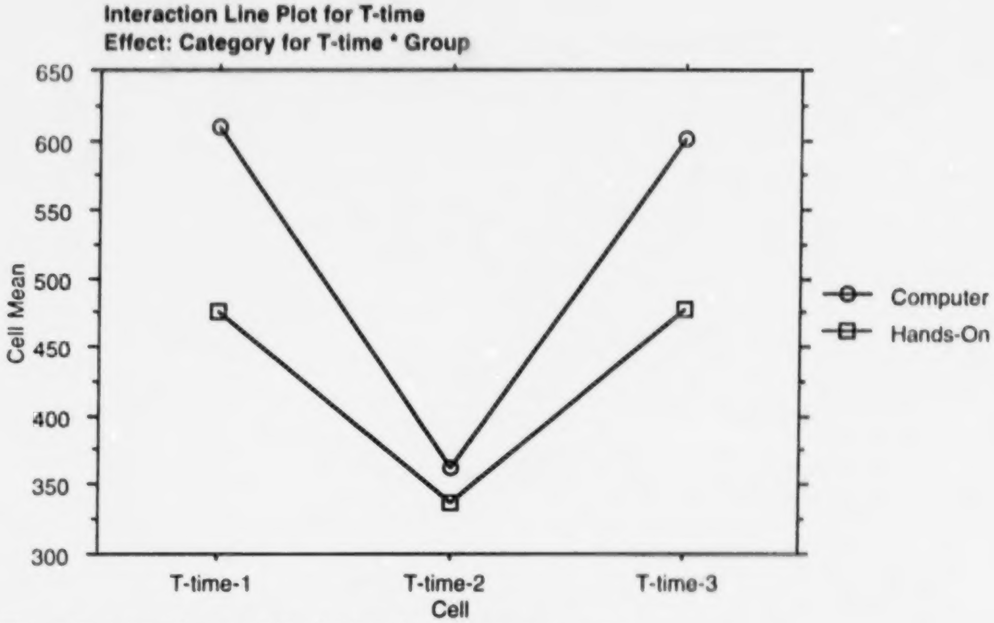

Figure 5. Interaction graph for the time for performance measure.

It would be nice to conclude that the computer-based tutoring was just as effective as the hands-on tutor instruction. Unfortunately, that is not possible. Although accuracy seems to be the same for both groups, speed seems to differ. Among many possibilities, I think that two are of particular interest. The first idea is that the nature of the memory stores are different for the two groups. It would be interesting to perform some interviews with the subjects in each group to attempt to tease out the nature of their representations. A second idea for further study could be that the computer-based training "mastery" learning implementation is not robust enough. In fact, I initially put mastery determination in the hands of the learners and they could select which problem to work on. I found that many did not even do all the problems once. Therefore, I implemented an easy to implement strategy. A more "intelligent" strategy might optimize their practice and produce real mastery that would result in speed improvements.

I also examined the learners' reactions to their instruction with a questionnaire. There were no differences between the two groups. Finally, we used Keller's (1987) ARCS model to determine if there were differential motivational effects. Again, it was found that there was no significant difference between the groups. This would support the idea that the computer tutor was the same as the hands-on instruction.

Conclusions

I was interested in comparing a computer-based-hypermedia-simulation-ITS with the best instruction I could devise. The results are somewhat confusing. While learners in both groups were comparable in terms of accuracy of performance, opinions about the quality of the instruction, and opinions about how motivating each of the instructional treatments were, there were differences in how fast they were able to perform procedures. I believe that this difference in performance can be attributable to the fact that

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the computer group was required to transfer their learning from the computer world to the real world, something not required of the hands-on group.

If each of the 47 steps in the operation of the MSRT required a mapping step for the computer group, then this difference would show up in their speed of performance. Further, the mapping is a process, not a memory. The knowledge of the step to carry out is a memory. The accuracy measure in the instrumentation indicated that there was no difference between the groups. They had similar "amounts" of memory. The speed was different. Therefore, one could argue that it is this mapping of domains that causes the difference in speeds.

An alternative explanation would be that the computer group was in the declarative phase of skill acquisition and the hands-on group was at a procedural stage of learning (Anderson, 1982). We have a difficult time with this interpretation. One problem is that the hands-on group essentially performed the procedures once. According to Anderson, this acquisition occurs over a period of time. The computer group averaged 19 problems completed during the learning phase of the experiment (the tasks were broken down into six procedures, so they did varying numbers of these six procedures, but did on average 19 problems in total). Therefore, deferring to Anderson does not make as much sense.

The bottom line is that taken as a whole, hands-on instruction is better than computer-based instruction as conceived in this experiment. Therefore, one ought to conclude that the Army ought to use hands-on training for all instruction. This is not completely true. The first problem is that in order for one MSRT to call another, $5 million worth of equipment needs to be operating. In addition, 8 people need to be manning that equipment. This is quite costly. Another consideration is that the $5 million worth of equipment is also going to be used to provide hands-on training for its operators. So it may be likely that you have your people ready to perform the hands-on activity and it is not possible because the switching shelter is not operating correctly. I hesitate to say, that I never could make a call on the MSRTs used for testing. The experimenters explained how the equipment would have worked if it was operating correctly. Fortunately, these aspects are only at the very end of the procedures effecting the last 10 steps or so. Other equipment may not be so designed.

The MSRT Tutor always worked. It always generated the correct sounds. It always displayed the correct lights. It was much more consistent than the actual equipment. Further, you need to pay someone to stand by and provide the hands-on training. With the Tutor, this is unnecessary. Therefore, it would seem that the Tutor is more cost effective than the hands-on training. However, I would not be honest if I did not admit that the hands-on experience was vital and should occur at some point, but the Tutor can be most valuable in the initial training phases.

I would also like to conclude with the comment that we need more research (we would be out of a job if we didn't). There are a variety of things that can be done to minimize transfer problems. I already have a multimedia version of the Tutor that uses digital movies to explain tasks to perform. These movies could make these mapping and the representation be more like the actual equipment. Unfortunately, these movies take up much disk drive space (1 megabyte versus 19). There are cheaper solutions that may be just as effective. For example, digital still images could be just as effective as digital movies and because there are only three main pieces of equipment in the MSRT, only three digital pictures would be required. This would not take much storage. It does, however, require at least a VGA monitor. The MSRT Tutor was implemented in EGA graphics because of the huge number of EGA capable machines in the Army. These are not capable of displaying the photo realistic images.

Other materials and adjunct teaching strategies might improve the Tutors performance including job aids and strategy instruction. These can have an immediate impact on performance and potentially can begin to address the decay problem.

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Driving Simulation Research at the University of Iowa

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Abstract: This paper describes research on simulator sickness and driver performance in the Iowa Driving Simulator. The four independent variables were driver experience, driver gender, width of the visual field, and presence or absence of motion. The primary dependent variables were symptoms of simulator sickness, driver ratings of the simulator's realism, and driving performance. Predictions for driver experience were confirmed, that novice drivers would experience less simulator sickness and rate realism higher than experienced drivers. Predictions for gender were confirmed, that females would experience more simulator sickness than males, but would rate realism the same as males. Predictions for visual field were not confirmed, that a wider visual field would result in greater simulator sickness and greater realism ratings. Predictions for motion were not confirmed, that the presence of motion would result in more simulator sickness and greater realism ratings.

The Iowa Driving Simulator

The Iowa Driving Simulator, or IDS, is a project of the Center for Computer Aided Design (CCAD) of the College of Engineering at the University of Iowa (Haug, 1990). Although the simulators have been designed and constructed by the College of Engineering, research with them is conducted by research groups from several departments including medicine, computer science, psychology, education, and engineering.

There are three vehicle simulators at CCAD. The high fidelity simulator includes a motion base with 6 degrees of freedom, 191 degrees of visual field in the front and 64 degrees in the rear, and realistic audio. Different model vehicle cabs may be mounted inside the simulator "sphere", although to date the main vehicles installed and simulated have been a Ford Taurus, a Saturn sedan, and a military HMMWV (pronounced Humm-Vee, and standing for High Mobility Multipurpose Wheeled Vehicle). The simulator can run with different scenarios, that is different roadways, scenery, etc., and during each run extensive data is collected on all actions taken by the driver.

There is also a medium fidelity simulator with fixed-base, that is no simulation of motion, and an increased visual resolution capability. This can also run with different model vehicles. It is capable of the same scenarios and data collection as the high-fidelity simulator.

Lastly, there is a low fidelity and substantially lower cost simulator without motion, with lower fidelity visuals, limited scenarios, and restricted data collection capabilities.

The University of Iowa has received a large grant to design and build the National Advanced Driving Simulator, scheduled for completion in several years. This is expected to include a more sophisticated linear motion base and 360 degrees of visuals.

Research projects in progress at the center include human performance research, traffic safety research, driver health research, vehicle engineering research, and basic simulator design research.

Our own work concerns human performance research, including the use of driving simulators for training and for assessment. The research reported here deals with the causes of simulator sickness and how that and other variables affect user performance in driving simulators. Simulator sickness is a phenomenon akin to regular motion sickness, although the causes, symptoms, and persons susceptible to it are often different (Reason & Brand, 1975; Reason, 1976; Kennedy, Dutton, Ricard, & Frank, 1984; Frank &Casali, 1986).

This study utilized the high fidelity simulator with the Ford Taurus. The research participant, i.e. the driver, and the experimenter, who sat in the front passenger seat, enter the simulator by a staircase. The simulator consists of a sphere mounted on the hydraulic motion base. Video projectors inside the sphere (3 for the front view and 1 for the rear view) project animated scenery, roadways, and other moving vehicles on the inside walls of the sphere, which act as the video screen. There are also several speakers for realistic audio. The rear screen permits the driver to use the side-view and rear-view mirrors normally. The driver can look directly to either side and still see realistic images.

The motion base, when used, is programmed in synchrony with the visuals, so that as the driver turns, stops, or hits a bump, the visuals reflect the motion and the motion base attempts to recreate the correct feel.

Although the Iowa Driving Simulator is technologically very impressive, many people question (and understandably so) the value of a multi-million dollar driving simulator. It is one thing to spend a few million dollars on a simulator for a passenger airliner which itself costs 50 to 100 million dollars, or a military fighter jet which costs even more. But an automobile only costs 15 or 20 thousand dollars. Why spend several million to simulate it? There are several reasons. They include the capacity for exact replication of events, extensive and detailed data collection, safety while teaching or assessing dangerous conditions or maneuvers, the capacity for artificial guidance and feedback, increased efficiency by compressing the time-frame, and the ability to do either part-task or full-task training.

But there are other impediments, besides the considerable cost, for driving simulator use in training and assessment. Our two main concerns are simulator sickness and validity (Whiteside, 1983). Simulator sickness, which occurs in about 20 percent of the Center's younger (that is under 60 years old) and 33 percent of the older research participants, varies from slight sensations of lightheadedness to extreme nausea. The existence of simulator sickness decreases the validity a simulator. That is, it decreases the confidence we can have that a person's performance in the simulator is the same as, or predicts, what their performance would be like in a real vehicle. For that reason, our main interest is to determine the factors which most influence the occurrence of simulator sickness and devise methods for eliminating it as much as possible. Of course, simulator sickness is just one phenomenon which affects the validity of a simulator. In general it is believed that simulator fidelity, or realism, is the main factor affecting validity (Gagne, 1954).

Experimental Design and Procedure

The study we have just completed with support from the Link Foundation investigated the effects of four factors on simulator sickness and driving performance in the simulator.

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The factors were driver experience, driver gender, width of the visual field, and presence or absence of motion. Our subjects were either junior high school students with no driving experience or adults with many years of driving experience. All subjects drove the same high-fidelity simulator, but some of them had the motion base turned on and some had it turned off. Similarly, some subjects had a complete 190 degree visual field (in front) and some had a more narrow 60 degree visual field. Experimental design was four factors completely crossed.

Participants drove the simulator one at a time, always accompanied by the experimenter. Before driving the simulator, participants took a few short tests to assess their sense of balance and other feelings of physical state which may be affected by simulator sickness. They answered a questionnaire about driving experience and if they had any history of ordinary motion sickness.

They were then taken into the vehicle simulator. The experimenter always sat in the front passenger seat and directed the driver as to when to start, turn left or right, stop, and so on. The roadway consisted of a rural portion, a freeway portion, and an in-town portion. It took about 40 minutes to complete. While driving, the experimenter observed and took notes on any symptoms of simulator sickness and wrote comments on important aspects of driving performance, such as if the driver went off the road.

After driving, the participant was given a short test and questionnaire to assess any symptoms of simulator sickness, and to get the participants opinion of the realism of the simulator.

Hypotheses

Our main hypotheses were that non-drivers would experience less simulator sickness than drivers, that females would experience more simulator sickness than males, that a wider field of view would produce more sickness, and that motion would produce more sickness.

We also expected the following differences for perceived realism -- that experienced drivers would be able to differentiate realistic and unrealistic conditions better than non-drivers, that the wider visual field and presence of motion would increase perception of realism, but that there would be no difference in perceived realism for females versus males.

Results

Our findings confirmed the hypotheses for both experience and gender. Non-drivers experienced much less simulator sickness, irregardless of the other factors. Non-drivers also rated realism higher than experienced drivers, the latter being rather critical of the simulator's realism.

Experienced drivers had more or less simulator sickness depending on the other factors. Female drivers had considerably greater incidence of simulator sickness and more females dropped out of the study because of simulator sickness. Yet there was no difference in perceived realism for males versus females.

Our hypotheses concerning the two fidelity variables, visual field and motion, were not confirmed. The width of visual field affected neither degree of simulator sickness nor the level of perceived realism.

Nor did the use of motion have the affect we predicted. However, there was a trend opposite our prediction for motion and perceived realism. Subjects using the simulator with motion rated the realism lower than those using the simulator without motion.

What affect did our factors, or the occurrence of simulator sickness, have on driving performance? We have only begun to analyze that data. Each participant's 40 minute driving session produces approximately six million data points. Our continuing analysis is focusing on two questions. What impact do our factors (gender, experience, visuals, motion) have on performance, and what impact does the occurrence of simulator sickness in drivers have on their performance?

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Discussion

Our next step it to investigate in more detail those people who do suffer simulator sickness. This should allow more sensitive investigation into its causes and possible ways to control it. Future use of the simulator for either research or training depends on being able to reduce simulator sickness, either through practice, scenario design, fidelity adjustment, or simulator improvement. We plan to pretest participants in a short run to determine who will experience simulator sickness. We will ask those participants to return for experiments in which we vary conditions more carefully (such as the type of motion) or try methods intended to reduce their incidence or severity of simulator sickness, such as pre-training or starting out on a straight roadway with few turns.

How do our results relate to the current literature? Simulator research to date does not indicate any gender differences, but that is because almost all simulator research has been with men in predominately military type vehicles -- planes, helicopters, tanks, and submarines (Kennedy, Dutton, Ricard, & Frank, 1984). The potential use of simulators for ordinary ground vehicles (cars, trucks, buses) is much greater, with equal numbers of men and women as operators. It is essential that research and development with driving simulators consider the variable of gender.

Concerning fidelity variables, previous simulation research and literature reviews, which have rarely done direct experimental comparison of fidelity variables, as well as being based largely on military devices used by men, has suggested that increasing field of view or adding motion will increase simulator sickness (Casali & Wierwille, 1986). Our results have not confirmed that, especially concerning visual field of view.

Previous research has not dealt much with the experience variable. The finding that non-drivers experience little simulator sickness and rate simulators relatively higher in realism, has positive implications for simulator design and use. Simulators for training and assessment of novices may be quite adequate even with low levels of fidelity, with concomitantly lower cost and possibly less incidence of simulator sickness.

Determining the causes of and ways to control simulator sickness are an essential step in creating simulators which are valid for research and training. For example, there is great interest in the use of the simulator for medical research investigating the effects of aging, medication, eye impairments, and the like on driving. Obviously the use of a simulator for such research is much safer and therefor more ethical. But if participants experience extensive simulator sickness, how are we to know if impaired driving performance is the result of a medication or the result of simulator sickness?

We believe that simulator fidelity is one of the important determinants of simulator sickness. But we are interested in simulator fidelity for other reasons. Higher fidelity drives up the cost of a simulator. If particular tasks, such as a medical research experiment or a state driving test, can be done with a lower fidelity simulator and still be valid, it will be much cheaper. For a long time it was believed that higher fidelity is better and leads to greater validity (Gagne, 1954; Miller, 1974; Hays, 1980). Years of research with flight simulators has cast doubt on that. Our intention is to conduct research on the affect of varying fidelity on validity for different purposes, such as for instruction versus assessment. It has long been contended that greater fidelity is needed for a test than for instruction (Gagne, 1954). Research in visual impairments may well require high visual fidelity but allow low kinesthetic fidelity, that is, may not require the use of an expensive motion base.

One of our goals is to try to control simulator sickness and at the same time optimize instructional effectiveness through the use of gradually increasing fidelity (Alessi, 1988). This might be done be starting instruction in a low fidelity simulator, which is cheaper, and moving to higher fidelity simulators as the learner accommodates and as performance improves. It may also be done with dynamic fidelity, increasing and decreasing realism as a function of the learner's performance and well-being. However, this technique requires a high-fidelity simulator even for lower fidelity conditions, so would not benefit from as great a cost savings.

Our finding that non-drivers experience little simulator sickness and rate the simulator high in realism lends credence to the use of low fidelity simulators for teaching and assessing driving performance with beginners. It may not even be necessary to gradually increase fidelity with non-drivers, but to go directly from low fidelity simulators to real vehicles.

The next step in this program of research, and which we are already beginning with data from the current simulator sickness study, is to determine the best methods of assessing driving performance in the simulator. There are different ways of approaching this, from very atomistic analyses of driver actions, such as steering wheel control and lane deviation, to task analysis of the more global aspects of driving performance, such as maintaining safe speed, passing, turning, and stopping.

Obviously there are a lot of variables and considerations in the use of driving simulators for both research and training purposes. At a minimum, the problems inherent in simulator sickness must be overcome to gain the advantages engineers are fond of claiming for their simulators.

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Using Computer Simulations in Problem-based Learning

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Abstract: Although Problem-based Learning (PBL) has been adopted as a method of instruction for many health education institutions world-wide, it still has many opponents. The major objections to PBL are: (1) PBL is an inefficient method of instruction since it requires students to gather information through self-directed learning, (2) PBL is perceived as costly since it requires a greater investment of faculty time to function as tutors, and (3) PBL is more difficult and costly in terms of evaluation of student learning. Furthermore, there is a lack of direct evidence that all the goals of PBL are being met. This paper discusses a modification of the PBL format and the use of computers to alleviate these difficulties associated with problem-based learning.

As medical knowledge has grown so has the need to improve the methods of instruction employed in training individuals employed in the healing arts. Problem-based learning is an instructional format which has been developed in an attempt to meet the need for improved instruction in health-related sciences. According to Barrows (cf. Norman & Schmidt, 1992), the goals of PBL are: (1) to promote self-directed, life-long learning, (2) to foster clinical reasoning or problem-solving skills in students, (3) to enhance acquisition and retention of knowledge by situating learning in the context of its real-world application, (4) to enable students to better integrate basic science knowledge into the solution of clinical problems, and (5) to increase student intrinsic motivation.

Problem-based Learning Format

Barrows (1983) provided a detailed explanation of the problem-based learning format. PBL is implemented in small groups of from 5 to 6 students and a faculty tutor. At the beginning of the week the tutor gives the students a clinical problem which they are to attempt to solve without receiving an explanation of the problem solution. After presentation of the problem the students attempt to identify the nature of the problem and to generate as many hypothesis as possible. As the students discuss the case, they are encourage to seek information relevant to the patient's history, physical examination, and diagnostic tests. This information is provided by the tutor who has access to the printed case book for each problem. Once the students have gathered information from the case book they choose from their original list of hypothesis what they believe are the mechanisms causing the patient's condition. At this point the group, with the assistance of the tutor, decides what learning issues are involved in the case, decide how to go about resolving these issues, and delegate among themselves assignments for resolving these learning issues. Each student may take a different topic and use various learning resources in researching his or her assigned learning issue. After a pre-determined length of time (usually 2 to 4 days) the group reconvenes and is again guided by the tutor through an examination of the same case. In this instance, however, the students act as experts for the particular topic they were assigned. When the students have finished a case they critique their performance and summarize what they have learned and how it relates to what they have learned in the past. In the whole process, the tutor is never to act as a dispenser of knowledge, but rather as a facilitator of the interaction among the students. Other faculty

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members may be assigned as resource persons that may be consulted by the students but they are not allowed to solve the case for the students. Formative evaluation for the students in performed by the tutors and students as they engage in the PBL methodology. Summative evaluation occurs periodically via the means of standardized simulations administered by technical personnel. There are variations to the PBL format just described. Other schools vary the size of the group, method of presentation, the amounts and timing of feedback, and the means of evaluation. However, this paper will discuss PBL in terms of the curriculum described by Barrows.

PBL Strengths and Weaknesses

The Goals of PBL

Although problem-based learning is generally well-accepted by the schools and students using this mode of instruction, many questions remain as to whether or not the goals of PBL are being accomplished. Research has been conducted that has revealed several weaknesses in the problem-based learning curriculum. One study (Patel, Groen & Norman, 1991) examined the effects of conventional and problem-based medical curricula on problem solving. Although students in the PBL curriculum were able to provide more detailed explanations of the basic science concepts involved in the cases presented to them, they also displayed a tendency to generate many more errors than the conventional curriculum students. Patel and colleagues argued that the errors committed by the PBL students were probably due to the scarcity of feedback given by their tutors as well as to confusion resulting from the intermingling of instruction in basic and clinical sciences in the PBL curriculum. They also found that the problem-solving method taught to PBL students may interfere with the normal problem-solving methodologies of expert clinicians.

Other studies question the ability of instruction to teach general problem-solving skills. In his review of research on problem solving, Norman (1988) noted that the main difference between expert clinicians and medical students is that clinicians generated better hypotheses, not that they were better problem solvers. Norman also found that an expert is an expert because he has ready access to the domain-specific knowledge which enables him to recognize the pattern of the problem before him.

In their review of research on problem-based learning, Norman and Schmidt (1992) found that (1) there was no evidence the PBL improved general problem-solving skills; (2) PBL tends to reduce initial levels of learning but improved long-term retention of knowledge; (3) PBL may enhance transfer of concepts to new problems; (4) PBL tends to enhance intrinsic motivation in students; and (5) PBL seems to enhance self-directed learning with this tendency being retained by the learner.

Inefficiency of PBL

Patel, Groen, and Norman (1991) found that the students in a conventional medical curriculum learned to solve clinical problems more efficiently than PBL students. In problem-based learning, students are not typically given a solution to the problems they are asked to examine. Instead they are asked to discover the problem solution through independent research, group discussion, and tutor guidance. Needham and Begg (1991) conducted a series of experiments comparing problem-oriented training and memory-oriented training in their ability to promote spontaneous analogical transfer. As a part of their research, Needham and Begg gave one group of students instruction on how to solve a given problem and asked them to remember the problem solution so they could solve additional problems. A second group of students were given the same problem and asked to attempt to solve the problem before the problem solution was given to them. However the second group of students were not asked to remember how to solve the problem. Both groups were then given problems to solve which were analytical to the first problem. It was found that the group who was asked to attempt to solve the problem before attempting a problem solution were more successful at transferring the problem solution to an analogous problem than was the memory-oriented group. Needham and Begg also discovered that experimenter-provided explanation of the problem solution was necessary if transfer was to occur. It appears from these findings that PBL could be improved, both in terms of efficiency and in promoting spontaneous analogical transfer of problem solutions, by allowing tutors to administer appropriately timed feedback

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concerning problem solutions.

Administrative Cost of PBL

As far as the cost of the problem-based learning curriculum, Barrows (1983) found that while the initial costs of implementing PBL were higher, normal operating costs were the same as those of conventional curricula. Barrow's assessment of costs, however, may not be applicable in schools that operate at substantially lower budgeted levels, such as colleges of veterinary medicine. The fixed costs associated with PBL may fit within the budgets of medical schools but be beyond the means of other institutions of health care education. Regardless of the affordability of the PBL curriculum, finding a way to lower the cost of its administration would not be a wasted effort.

Evaluation

Barrows (1993) describes the benefits of using simulated patients as part of a standardized simulation for student assessment. While this method of student evaluation could be assimilated with minor modifications to other fields of health education, the cost of this assessment technique would exceed the cost of administering evaluation in a conventional curriculum by a significant amount. Alternate methods of student assessment need to be explored in order to find evaluation strategies comparable to using simulated patients but at a reduced expenditure of time and money.

Using Computer Simulations in a Modified PBL Curriculum

The preceding evaluation of the strengths and weaknesses of problem-based learning suggests the need for a modification of the PBL curriculum to amend problems associated with its lack of efficiency as well as the utilization of computers to improve its economy. The following scenario is one possible means of employing these changes. In this method of instruction, the students will meet initially in small groups. The groups will use a computer to access a previously assigned prototypical problem. The computer will allow students access to history, physical examination, and diagnostic data for the case being presented. At various stages of the program the students will be directed to identify learning issues associated with each problem and enter them into the computer. As the various groups work through the problem, their progress may be monitored at any time by the instructor via a local area network or collected and evaluated at a later date. From the list of learning issues, each student will be assigned a research topic. The research will be conducted in one day rather than in two to four days however. When the students reconvene they will reexamine the example problem and attempt a solution, again using the computer and their progress being monitored as before. Next all the groups will meet together with the instructor. Regardless of whether or not the students reached a proper problem solution, the instructor will provide an expert description of the problem solution and give each group written feedback concerning their efforts. As a part of this process, the students will receive instruction in the basic science concepts associated with the problem solution. This procedure will be repeated for a group of prototypical problems designed to cover a unit of instruction. After the students have completed a unit of instruction individual students will use the computer to practice problems analogous to the problems presented in the unit. As the students attempt to solve the analogous problems, the computer will again track the method by which the attempts are made and record this information in a database record for the student. The computer will compare the student's problem-solving methodology to a standardized assessment form and record the differences. The next step will be to give the student feedback as to how his attempt at the problem solution may vary from the standardized format. According to Norman and Schmidt (1992), it is important for immediate feedback to be given to students after they have attempted to solve a problem. Finally, at the end of each unit of instruction, the students will be evaluated on the basis of their performance on a standardized simulation administered by computer.

While the preceding instructional format is as yet untested in its final form, it should retain the advantages of the problem-based learning curriculum while compensating for its major deficiencies. By interjecting the instructors explanation of the problem solution and instruction in the basic sciences associated with each problem solution, greater instructional efficiency should be enjoyed. This strategy

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should also serve to promote transfer of problem solutions to analogous problems. Use of the computer in presenting problems, monitoring student progress, and administering assessment should provide PBL with greater economy. Although the outlook appears promising, further research is needed to assess the potential benefits of this instructional strategy and its proposed method of implementation.

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Teaching Problem Analysis by a Computer Simulation

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Abstract: The aim of the project Problem Analysis with Computer Organized Simulations (PACOS) is to solve two problems a course on unsteady flow analysis suffers from: students are unfamiliar with problem analysis and students start studying too late. PACOS was used for the first time in November 1993. The results are very promising. Students that use PACOS get familiar with problem analysis and receive higher exam scores than students that do not use PACOS. A large number of students start their study early (during the first half of the course), especially the good students. Furthermore, the PACOS activities of good students appear to be qualitatively different from those of poor students.

As participants of the project Problem Analysis with Computer Organized Simulations (PACOS) the authors have created a new user-interface which was used successfully at the end of 1993. The project concerned the effective use of simulations in education, including educational research. It was sponsored additionally by Delft University of Technology.

The old course and its problems

The course in question consists of three elements:

- Lectures concerning tidal wave propagation, flood waves in rivers, harbour oscillations, etc. Over a period of 7 weeks, 2-hour lectures are presented twice a week.
- A syllabus offering the theoretical foundation of these phenomena.
- Three assignments in which students individually analyze representative phenomena.

The students complete the course by taking an exam.

In the past these three elements were challenging enough to prepare students for the written examination successfully. In recent years, however, the more open examination questions regarding design, prediction and interpretation gave insufficient results. These might have arisen because of the two following problems. First, students are not familiar with problem analysis and therefore are not skilled in answering these types of questions. Second, a large number of students are not prepared sufficiently to take the exam. These students start studying too late, although they are invited (from the first week) to study the physical aspects of wave propagation including storage, inertia, friction, reflection, resonance etc.

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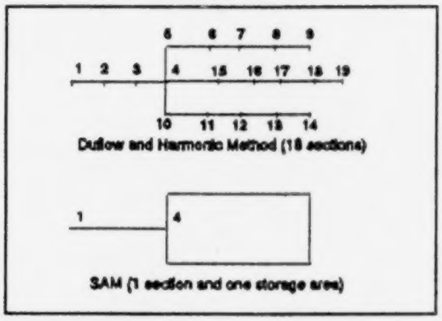
The philosophy of the new course

The new course was intended to overcome the two problems mentioned above by stimulating the self-instruction regarding mathematical and physical aspects of the phenomena during the first two weeks of the course and by basing this self-instruction upon problem analysis. Students appear not to be stimulated by lectures and assignments only. The new course offers an extra stimulus by using a new instructional format called Problem Analysis with Computer Organized Simulations (PACOS). Students learn to use three analytical models more effectively and to apply numerical calculations by means of a non linear simulation model called DUFLOW.

According to this idea, the structure of the course in the first three weeks was changed: earlier explanation and application of analytical solutions, the first of the three assignments in a shorter period of time, and more attention to predictions by means of simple analytical solutions. In the fourth week, three days were available at which each of a maximum of 200 students had access to a computer for two hours of using PACOS.

In the new course students study the physical aspects of a tidal irrigation system (IRRSYS). Attention is given to the Harmonic Method, applied to a network of 18 sections. Furthermore, the student learns to use a 'simple analytical model' (SAM) for stating predictions concerning IRRSYS during the problem analysis procedure. The predictions based on SAM, which contains only one section and a discrete storage area, are stated within a few minutes. Furthermore, they seem to correspond well to the results of excessive calculations by DUFLOW, based on a non-linear model that contains 18 sections. (See figure 1).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Duflow and Harmonic Method (18 sections)
1
4
SAM (1 section and one storage area)

Figure 1. The two models of IRRSYS as used by the three calculation methods

Before starting PACOS students have to take a test called PACO. Most questions contained in PACO are aimed at changes in IRRSYS and solved by applying the Harmonic Method. Students that fail the test are not permitted to use PACOS.

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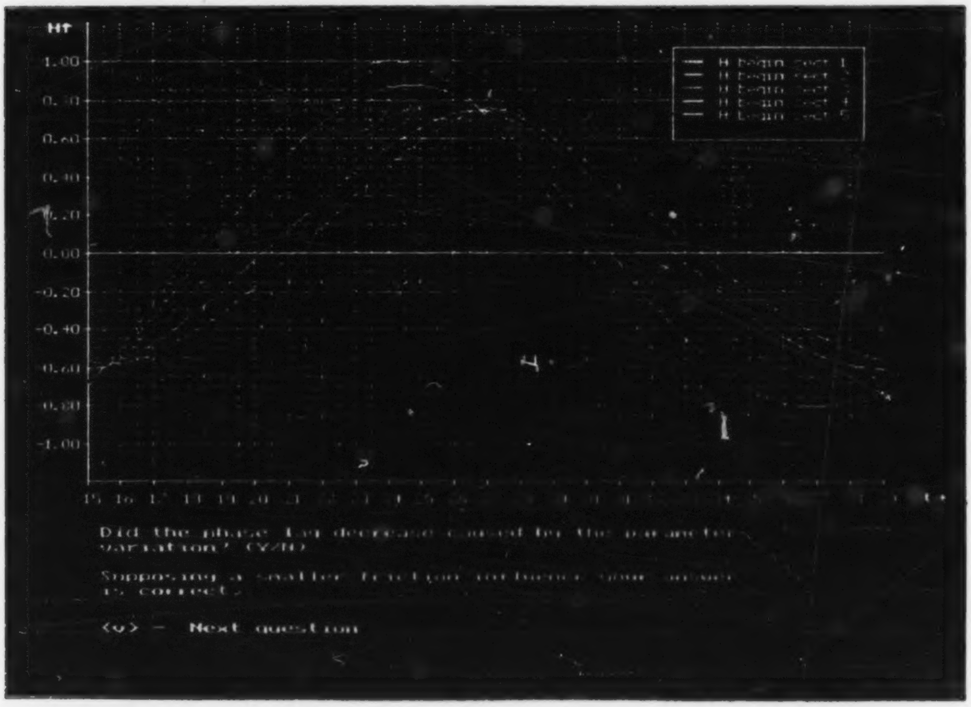
PACOS

PACOS is a new user-interface built upon the heart of a simulation package. This user-interface supports the student in four ways:

- it presents assignments to the student, in coherence with the steps in an analysis strategy;
- it forces the student to state a prediction before running the simulation;
- it simplifies the complexity of the input of the simulation package;
- it presents questions in order to interpret simulation results.

Prior to starting PACOS, students are invited to prepare some parameter variations individually and use SAM to state predictions of the tidal difference and the amplitude of the discharge. In PACOS each student is presented 10 assignments. In the first 6 assignments the student is asked to think of a variation of IRRSYS by changing one parameter in one or more sections. The student is free to choose any one of the available parameters and is free to decide upon the magnitude of the change (only very extreme changes are not accepted). In the two following assignments two parameters can be changed simultaneously. The two last assignments are of a different nature: instead of analyzing changes in IRRSYS, the student has to construct a variation of the network system that reaches a certain goal. An example of such a goal is: the velocity in the tidal inlet has to become smaller than 0.5 m/s.



Did the phase lag decrease caused by the parameter variation? (Y/N)

Supposing a smaller friction influence your answer is correct.

<v> - Next question

Figure 2. An example of a screen containing output and an interpretation question

The first eight assignments are related to an experimental cycle well known in theories

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of scientific reasoning (Khlar & Dunbar, 1988) and have been studied in educational research (de Jong & Njoo, 1990; Reimann, 1989):

1. Analyze the situation.
2. Generate a hypothesis.
3. Test the hypothesis.
    - 3a. Design an experiment and state a prediction.
    - 3b. Run the experiment and interpret the output data.
4. Evaluate the results.

In PACOS students have to state a realistic prediction before they are allowed to run the simulation. They can use SAM to evaluate the prediction before running the simulation. Students learn to use predictions in order to get insight in unsteady flow analysis as well as to prevent useless experiments and an overload of data. The educational relevance of stating predictions and confronting these with observed outcomes has been emphasized elsewhere (Friedler, Nachmias & Linn, 1990; Reimann, 1992).

The use of DUFLOW, a tool for practitioners and researchers, is rather complex for students. It will take an inexperienced user at least a couple of hours to get familiar with DUFLOW and another couple of hours to complete some assignments. If that person is not familiar with computers, it might even take days. The PACOS user-interface is that simple that even students who are not familiar with computers are able to finish the assignments within the time limit of one and a half hour and concentrating on problem analysis only.

The instructor can use a simple file editor to create questions which are presented along with the graphs prepared by PACOS (see figure 2). These general questions assist the student in interpreting the output by directing his attention towards interesting aspects of the graphs. These graphs illustrate the relevant physical aspects of wave propagation.

Method of evaluation

The course in question is scheduled in the third of four years of the academic study for Civil Engineer. The course started in November 1993, and the exam was scheduled in January 1994. A total of about 145 students that entered university from 1990 onwards enrolled in this course.

The procedure was as follows:

- A pretest was given during the lectures at the end of the third week.
- The computer-based instruction was scheduled in the fourth week. Students worked with a computer for 2 hours, in which both PACO (0.5 hour) and PACOS (1.5 hours) had to be finished. Students that failed PACO were not allowed to start PACOS.
- A posttest was given during the lectures at the end of the fourth week.
- A questionnaire was handed out during the lectures at the end of the fifth week.

Both the pretest and the posttest contained questions related to problem analysis.

Results

The results of the various tests were mixed. On the one hand, the pretest-scores (taken by 67 students) as well as the posttest-scores (taken by 57 students) were bad. These tests were passed by 11 and 7 students respectively. All of the 7 students that passed the posttest did use PACOS. On the other hand, the PACO test-scores were good. A total of

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122 students took the test, 113 of whom passed it.

There was no complete overlap between PACOS-users and students who took the exam. Of the total group of 145 students:
- 101 used PACOS, 28 of whom did NOT take the exam,
- 109 took the exam, 36 of whom did NOT use PACOS,
- 8 did neither.

On the exam, the students that did use PACOS outperformed the students that did not use PACOS (t=2.13; p=.018). This difference is also found for the PACO-test (t=2.43; p=.013) and the posttest (t=2.15; p=.020), but not for the pretest (t=-.47, p=.319). These findings seem to suggest that students that did use PACOS did start studying in the fourth week (after taking the pretest but before taking the PACO-test) and were better prepared to take their exam.

Of the students that participated in PACOS, a number of 59 students completed assignments 1 to 8 successfully. Assignment 9 was accomplished successfully by 33 students, the more difficult assignment 10 by only 12 students.

The predictive power of PACOS

For each student the computer kept a record during the use of PACOS. Among other things, this record contains for the first eight assignments the number of simulation runs (N), the number of different variables that were changed (Var), and the average value of the relative magnitudes of the changes (dVar). Furthermore, three performance measures were calculated:

- The difference between predicted and calculated tidal difference (dG). The measure ranges from 0 (good) to approx. 1 (poor).
- The difference between predicted and calculated amplitude of discharge (dQ), ranging from 0 (good) to approx. 100 (bad).
- The absolute value of a comparison of ratios (of predicted and simulated values) of G and Q. This measure tests the coherence of G- and Q-predictions related to the physical properties of the system and to SAM, even in case the dG and dQ measures are not very accurate (dG/dQ). The measure ranges from 1 (good) to 0 (poor).

Table 1
The correlation scores between the various measures

	dG/dQ	dG	dQ	pretest	posttest
dG	-.53				
dQ	-.37	.29			
pretest	-.12	-.09	.22		
posttest	.30	-.11	-.09	n.a.	
exam	-.05	-.04	.01	.12	.52

Because the dG/dQ measure took into account the coherence between the dG and dQ measures, it was expected to be the best predictor of the exam-scores. However, table 1 shows that the exam-scores correlate moderately positively with posttest-scores, but not

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with the other measures. The dG/dQ, dG and dQ measures correlate a little with the posttest-scores, and, not surprisingly, with each other. These findings suggest that at least two elements contribute to posttest performance. Since the posttest is based partly upon insight into IRRSYS, one element is related to PACOS. The other element is related to the exam (knowledge of and insight into unsteady flow analysis). The weak correlation between PACOS-measures and exam-scores might be accounted for by lack of transfer (students are not able to apply their insight into IRRSYS to other tidal systems).

The differences between good and poor students

One point of interest is the way in which good performers differ from poor performers. Two types of differences can be distinguished: differences in the way they do PACOS, and differences in their opinion on PACOS.

The figures in table 2 make clear that good students on the dG/dQ, Dg and dQ measures, compared to poor students, execute more simulation runs (N) and take more variables into consideration (Var). Furthermore, students that are good at predicting dQ use more reasonable variable changes (dVar). Thus, in general, the activities of good students during the PACOS session appear to be qualitatively different from those of poor students. Compared to poor students, good students analyze IRRSYS both more deeply (they start more simulation runs) and more broadly (they change more different variables), and the magnitudes of the changes they made were smaller (more realistic).

Table 2
The differences on N, Var and dVar between the 30% best and the 30% worst performers on PACOS-measures

	dG/dQ			dG			dQ		
	best	worst	*t*	best	worst	*t*	best	worst	*t*
N	5.20	3.88	2.14*	5.46	3.76	2.81**	5.08	4.00	1.75*
Var	4.52	3.44	2.32**	4.83	3.40	3.16**	4.60	3.36	2.78**
dVar	1.69	1.98	0,56	1.88	1.80	0.15	1.35	2.34	1.86*

$^{*}p < .05$; $^{**}p < .01$

In order to compare good and poor performers on their opinion on PACOS, a measure is needed to distinguish good from poor performers. One of three measures could be used: dG/dQ, dG or dQ. Since this measure correlates the best with the other PACOS-measures and with the posttest-scores (see table 1), the dG/dQ measure is used to make this distinction.

Opinions on PACOS were collected by means of a questionnaire in which students had to rate 27 items on a 5-point scale (1=low, 5=high). 58 students completed the questionnaire. When comparing good and poor students according the dG/dQ measure, 7 items show significant differences (see table 3). From the first two lines in table 3 it is clear that, compared to poor students, good students see a clear link between PACO and the preceding lectures and they indicate to have spent more time on preparation. Thus, spending more time on preparation has a positive effect on performance.

Furthermore, the last 5 lines seem to indicate that poor students have a more favorable opinion of PACOS. One point of interest is the fact that poor students are very positive about the interpretation questions that the lecturer has added to PACOS in order to confront students at the right moment with the important physical aspects in the graphs of PACOS.

Table 3

Significant differences in answers from poor and good students

	mean value poor std's (n = 35)	mean value good std's (n = 35)	*t*	*p*
PACO links up with lectures	3.00	3.53	2.01	0.026
Time spent on preparation	2.90	3.67	1.87	0.034
Simulations are useful	4.43	3.87	2.08	0.025
Simulations are motivating	4.05	3.40	1.80	0.042
Too many aspects are repeated	2.19	2.73	1.93	0.031
The interpretation-questions are useful	4.10	2.93	3.78	0.001
User-instructions are sufficient	3.90	2.67	2.03	0.027

Discussion

The course in question suffered from two problems: students are not familiar with problem analysis and students start studying too late. The use of new computer simulations, scheduled early in the course, was thought to offer a solution to these problems. The main purpose of this study is to evaluate whether this is true. Another purpose is to assess differences between good and poor students.

Concerning the problem of being unfamiliar with problem analysis, it is clear that a large number of students have improved their problem analysis skills by actual experience. A total of 101 students did use PACOS, 59 of whom completed the first eight assignments successfully. The 9th and 10th assignment were completed successfully by only a small number of students (33 and 12 respectively). These figures indicate that, halfway the course, students can handle the type of assignment related to the experimental cycle (the first 8 assignments) and that they have difficulties with the constructive type of assignment (assignments 9 and 10). Since the constructive assignments were scheduled at the end of the computer session, the bad results could be caused by time pressure.
The improvement of problem analysis skills is also shown by the fact that students who used PACOS received higher exam scores than students who did NOT use PACOS.

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Finally, nearly all students appear to appreciate PACOS and find the PACOS simulations both useful and motivating.

Concerning the problem of a late start, 45% of the students that completed the questionnaire indicate to have spent at least 4 hours of extra self-instruction on analytical solutions during the first half of the course. The fruitfulness of this extra self-instruction is reflected by the fairly high pass rate of the PACO-test, which amounts to approximately 90% of the students involved.

When compared to poor students, good students on the dG/dQ measure analyze IRRSYS both more deeply and more broadly, and the magnitudes of the changes they make are more realistic. Since they also indicate to have spent more time on extra self-instruction, spending more time on preparation has a positive effect on academic performance.

To conclude, the findings in this study suggest the following.

- Students that use PACOS get familiar with problem analysis and receive higher exam scores than students that do not use PACOS.
- A large number of students start their study early (during the first half of the course), especially the good students.
- The PACOS activities of good students appear to be qualitatively different from those of poor students.

However, from this study it cannot be concluded that early preparation will improve the ability to analyze problems: it might be that the good students just have more effective study habits or strategies. Furthermore, it cannot be concluded that PACOS improves the scores on tests related to problem analysis, at the moment the posttest was taken. The low posttest-scores might indicate that students still have difficulties to answer that type of questions easily within a short time and without the possibility of gaining credit-points. However, the students that pass the posttest are likely to be the best students at the exam.

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Machine Learning Approaches to Complex Automated Systems

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Abstract: Machine learning approaches can assist human productivity in using automated tools. There are numerous computer programs that help professionals and scholars complement their higher-order thinking skills, but such programs are complex and require so much effort to learn that users may spend more time on computer problems than they do on their domain tasks. Computer-aided instruction (CAI) often does not address the learner's problem and may be too time consuming. Hypertext information systems and electronic performance support offer means by which knowledgeable users can locate necessary assistance, but they must be aware of their own needs. Our research is focused upon machine learning which can individualize and prioritize the interaction between the user and the computer, adapting to the needs of users through pattern matching and other intelligent methodologies. Potentially, machine learning systems will automatically acquire knowledge from human-computer interaction in real world situations. This paper presents a methodology for an integrated broad-based research project.

Introduction

Technology has irreversibly changed our lives. Many of us pursued a teaching career, which meant something much different a few years ago. From the time of Socrates, the pendulum has swung back and forth between different philosophies of education. Does better understanding come about through questioning or memorization? Is experience more crucial than reading? Is a liberal education better than specialization? But the present shift is more than a pendulum swing. A few years ago, hypermedia and micro-worlds were unheard of. Accessing information meant visiting a large library with a good cataloging system. Education with and for technology has added new dimensions to every educational controversy and has made us educational technologists.

When Arnold and Huxley debated educational issues over a century ago, the outcome may not have had life-threatening implications. Now we are told that the world is different because of information technologies and that schools must prepare citizens for this different world. It has been estimated that, "A weekday edition of the New York Times contains more information than the average person was likely to come across in a lifetime in seventeenth-century England" (Wurman, 1989). Our educational systems are expected to teach students how to integrate vast quantities of information into their learning, thinking, and finally into their jobs. If present day education doesn't teach students how to benefit from information technology, they will be limited to unskilled positions (Rumberger, 1987) -- and a lower quality of life.

Computer Assisted Higher-Order Thinking

If the real pay-off of technology is to be realized, more and more professionals and scholars will use tools that will automate processes once considered too time consuming or unpredictable to be easily accomplished by humans. Technology can reduce some occupations to lower level skills; for instance, bar code scanners make the checker's job a matter of physical manipulation rather than memory and association tasks. However, the desired result is that people will be able to develop greater creativity and flexibility with the help of computers. The computer will foster thinking by functioning as a "cognition enhancer"

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which "combines the complementary strengths of a person and an information technology" and can "enhance human accomplishment by a division of labor: the machine handles the routine mechanics of a task, while the person is immersed in higher order meanings" (Dede, 1989). The result, much to be desired, is empowering the human mind to generate new solutions to complex problems or productive thinking (Mayer, 1983).

Learning to use computers in the manner described must become a natural process. In the climate of nurturing higher-order mental processes, education will never be complete. As new technology is developed, both young people in school and adults on-the-job will continue to study and learn. Schools and workplaces will become centers for extending human capacities through partnering with automated processes. And the partnering will be extended to include other human beings through telecommunications technology that will permit collaboration on a scale never before possible. These technologies are extremely complex, and as the complexity of the systems increases the difficulty of making productive use of them increases. Many professionals report spending more time mastering their computer systems than they do on their specialties. The task of using automation must be simplified even though the programs themselves and the domains they address can only be expected to become more complex.

Automated Tools

Automated tools are widely used. Professionals who practice musical composition, medical diagnosis, genetic research, financial decision making, and building design can all make use of computerized systems that aim to improve productivity and quality of results. Our research has been aimed at architects and engineers who may use many types of automated systems for design. Computer Aided Design (CAD) is the most commonly used automated tool in the design environment. The most widely used CAD systems can produce the detailed documents necessary for planning, review, construction and management of a facility, all higher-order mental processes. CAD systems have existed for over two decades and are still used mostly as drafting tools, rather than design tools, by many building designers (Liker, Fleischer, & Arnsdorf, 1993). However, two large surveys of government architects and engineers indicated that they found CAD helpful in the design process and that it allowed them to consider different possibilities in design (Shaw & Golish, 1988, and Shaw, Golish, Webster, & Yang,1991). Frequently designers respond to the question, "Is CAD a good design tool?" with the thoughtful explanation, "No, but I can use it."

CAD systems are complex and not easily supportive of concept design, but the indications are that any effort to improve designers' understanding of CAD systems would be generally useful and perhaps conducive to the design use of CAD. That potential plus their wide use has warranted that our research be conducted with standard commercial CAD systems. Our findings and approaches are applicable to instructional support for other systems that foster new ways of organizing and thinking about complex subject domains.

Research Background

The Effects of Previous Experience

In a previous study, (Shaw, 1992) it was found that architects and engineers were able to learn the commands of a well-known CAD system from an embedded tutorial. The program took advantage of the system's text and graphics as well as a programming language available through the CAD system to deliver instruction, provide exercises, measure success, and display feedback. The scores of the test subjects on a drawing test were comparable with classroom taught designers and they felt comfortable with their mode of learning. There was a wide range in the time required by the test subjects to complete the lessons and it did not correlate with their test scores. The interesting variable in the study was previous experience with another CAD system which did correlate with test scores. Those previously exposed to another CAD system also completed the test in less time.

In follow-up interviews (Shaw, & Golish, 1989) the hypothesis that conceptual-level understandings occurred in cases that had previous, different CAD experiencewas confirmed. That was not true with those who had experience with only the same system or none. These deeper understandings included ideas such as the manipulating of complex entities and the algorithmic nature of mirror copying objects. Multiple approaches in more than one CAD system gave the learners a varied view of the functioning of CAD. This finding concurs with the theory that acquiring advanced knowledge is dependent

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upon "having a diversified repertoire of ways of thinking about a conceptual topic" (Spiro, Coulson, Feltovich, & Anderson, 1988).

User vs. Machine Controlled Help

In an effort to artificially provide a conceptual framework for users, an adaptive system for administering procedural or conceptual help depending upon experience and behavior in the system was tested. The study was inconclusive, but suggested that users preferred to control the type of help they received (Shaw,Golish, Webster, & Yang, 1991). The test subjects reported that the word "help" had an association with procedural directions and was not consulted if they wanted the other types of assistance.

As a result of that study, we designed a system that allowed users to select supplementary information according to recognized types (graphic, example, practice exercises, procedures, etc.) as they proceed through instructional material. We theorized that novices might select a richer and more sequential path while those who had more sophistication with the subject would be more likely to design their own course and select assistance according to their needs and learning preferences. Preliminary results from a pilot study indicate that learners follow the patterns we predicted.

Tutorial Observations

To study assistance that might be useful to students using computer-aided instruction for CAD, advanced architecture students were observed as they learned CAD from an on-line embedded tutorial (Lee, 1993). The type of observation was participatory to the extent that advice was offered when students either requested it or behaved as if they needed it. The students were expected to complete a course of study and were tested on their skills. The observations included audio and video recording and direct questioning. One finding was that students had vocabulary and procedural problems that suggested a richer instructional environment might have been helpful for novice learners. The brief tutorial left many questions unanswered.

The study also found that students often could not understand what they had done when they executed commands. In the CAD system, many actions could not be directly observed and the system messages, if there were any, could not be interpreted by the students. Examples were cited, such as: intersections might not join but the error was not obvious on the computer screen; elements might be inserted into a drawing but they were not visible in the current screen views; or the computer would report that a complex element status had been "exploded" but that was not noticed or understood.

Meaningful feedback about what the students had accomplished was helpful for novices. This was true about productive actions as well as those that might be considered errors. If a student executed the correct action, but did not realize it, he or she often repeated the command unnecessarily, sometimes placing duplicate objects in the file. Simple feedback information seemed to constitute a valuable level of assistance and it might avoid user resistance to active coaching.

Assistance through Machine Learning

As our effort to provide a rich instructional support system progressed, we realized the extent of the task. We had designed over 700 source cards in our basic CAD support system and it was still in its infancy. If we were to expand the approaches to include people who use CAD systems for different special applications, examples of which range from clothing design to solar mapping, the amount of information needed to support users could become staggering. With networking and wide collaboration, a plan for incorporating new data could be developed, but the project could never be completed because of the continually growing information base.

As the size of the database expands to become more inclusive, it will become increasingly unmanageable for the user. Solutions such as tree-structured menus, "you-are-here" mapping, tracking user paths, and "hot" buttons may help, but people who need to learn particular skills or concepts in a reasonable amount of time will need assistance just to find their way through the available resources. It is easy to become lost just locating a file through the menus in Windows on a fairly large hard drive, and the CAD database potentially includes global references from distributed sources.

It has been suggested that user attributes could be filed and used to set priorities for particular types of users. Users could "fill in the blanks" about their characteristics and intent. We feel that would require extensive data input, would suffer from "self report" errors, and be difficult to change. Because of these problems, users might be excluded from access to potentially valuable resources. Such a system

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would suffer from inflexibility which is a problem in a dynamic environment. A more valuable type of support could be provided by monitoring users as they work, characterizing and classifying their behavior according to recognized user patterns, and using the patterns to determine assistance needs. Machine learning algorithms would be able to change as new patterns emerge and would learn about users from their work on the computer, in the context of actual documents, not from artificial cases.

It is likely that the user may not even recognize the need for assistance, but the computer can diagnose a problem by two types of comparisons, behaviors with known user models and design products with recognized standards. The goal is to offer non-intrusive assistance that would not interrupt the flow of ideas (Penzais, 1989) but would contribute information at the right time and in an appropriate way. Several difficult problems exist in the process of monitoring, characterizing, user modeling, and assisting. We have looked at behaviors that indicate skill level and have attempted to put them into a cognitive framework.

Indicators of Skill Level

A machine learning system was based on observations of users as they executed a drawing task in a CAD system. The drawing was a plan of a dimensioned staircase. The drawings of users who were experts in the same system, other CAD systems, and who were complete CAD novices were studied to model differences that could be recognized by a neural network. It was found that there were clear differences between the groups in the use of setup commands, translation commands, modify commands, and creation commands. For instance, novices used create-erase pairs frequently but CAD experts either used or attempted to find commands that would modify an existing element. Those who had used a different CAD system required the longest time for the drawing but their standards were much higher than the novices. Also, the quality of their drawings was much higher than novices. Our previous study (Shaw,& Golish, 1988) would suggest that with greater exposure to the system, their performance might surpass experts in the same CAD software.

User models were constructed on the basis of their test differences and accompanying verbal protocols. Based on the models, a neural network was implemented that would monitor the user behavior, recognize the skill level of the user and offer advice to increase productivity. The system mapped from the behavior of users to the user model and offered suggestions in a "non-disruptive" manner, flagging the user but not requiring attention. The pilot study demonstrated that monitoring user behavior was possible in a real world drawing environment (Bhavnani, Garrett, & Shaw, 1993).

Cognitive Considerations

Much of the research that we have discussed relates to current work in cognitive science. The real world requirements for this work make it subject to much current research concerning situated learning (Brown, Collins, & Duguid, 1989). Our studies of on-line help were aimed at delivering real world assistance in ways that would effectively fit different tasks, previous knowledge, and preferences. The need for understanding the factors that lead to the ability to acquire knowledge in complex domains (Spiro, Feltovich, Jacobson, & Coulson, 1992) is essential to this research. Such considerations have inspired our observation studies. The constructivist views of the relationship of experience to understanding relates directly to adaptive support for learning automated systems. Seeing the world of each person as a construction necessitates not only adaptation, but understanding the user's response to adaptation, and incorporation of the understanding into the system's knowledge base. Machine learning algorithms, by their inductive nature, are appropriate approaches to the dynamic requirements of learning complex technology in real world situations.

Ongoing Research

The goal of providing performance support in a real world context rather than a "sanitized" and controlled educational setting brought up questions about the complexity of the environment that must be understood by the system. What different kinds of domain knowledge and what levels of abstraction must the system address? To examine the issues, a group of researchers from the Army Corps of Engineers, the University of Illinois, and Carnegie Mellon University met during the summer of 1993. Disciplines represented in the group included Architecture, Civil Engineering, Computer Science, Information Science, Cognitive Science, and Educational Technology.

Some of the research questions had been explored before the meetings, but at this point it was thought necessary to communicate goals and formulate a research agenda for adaptive assistance within the concurrent engineering environment. Concurrent engineering, also called collaborative design, is thought to be one of the most complex processes humans undertake. It involves many participants through many phases over long periods of time and it has a history of poor communication and coordination (Garrett, 1993).

As we have stated before, teaching designers to produce high quality documents has been our objective for several years. These documents, legally required, are a convenient starting point for automating communication between the different disciplines and time periods involved in concurrent engineering. Beyond the questions of CAD performance lie the questions of freeing designers from routine problems in operating their systems so they can use CAD as a tool to enhance productive thought. Through the process of skillful refinement and modification in collaboration with other professionals, higher-order thinking is facilitated. This same principle can be applied in medical, scientific, and other decision making environments.

The results of our think-tank led to research areas concerned with user modeling, strategies for automatically acquiring this model, adaptive interface considerations which include both design and content, and mapping between the adaptive interface and the user model. The concern for automating the acquisition of the user model emerged as primary and seems to necessitate a machine learning approach. The research direction has been multi-faceted, beginning from several directions at the same time. The facets include standards of drafting and design (product model), modeling tasks as they exist in the design environment (user model), machine learning algorithms (system control and model acquisition), and software design tools. The objective is a collaborative effort to develop a rich learning environment for CAD that can lead into the wider domain of automated design.

We recognized that much of the work to be done was in uncharted territory and began to search for research methodology that would help us ask questions that would provide useful information. Two research projects were begun that would lead to knowledge about users' work environments and their drawing documents.

Ethnographic Observation

To design adaptive support for CAD users, we must understand their work habits and needs. Although some studies show the poor performance of CAD systems (Bietz, Langner, Luczak, Muller, & Springer, 1990), there has been little work done to study the users of CAD systems in their natural setting. Given the lack of information about these users, we turn to the ethnology branch of anthropology to guide us in studying their work habits and understanding their needs. Ethnology provides a methodology for studying the culture of any specific group. There have been cognitive experiments about capacities and time performance on computers (Card, Moran, & Newell, 1983), but cultural questions, (what is different and what is common in the way people interact with a computer application) and their social structure (who accesses what information and when) provides a mechanism by which we can test our assumptions in real world settings as we design adaptive assistance (Forsythe, 1993).

The relativist approach to ethnology holds that there is no single description of an event that is true, but there can be multiple descriptions of the same event, all being relevant. This along with such basic ethnographic tenants as that culture is both learned and dynamic relates directly to our research questions. Ethnographic observation also has the benefit of providing us with a clearer picture of the domain knowledge of CAD users and may indicate a mechanism for automatically acquiring and classifying data about user behavior.

Following the advice of Carroll and Rosson (1987) our observer visited an office with practicing architects using CAD systems in the role of a moderate participator. The first stage was to form a general description of the social situation (actors, activities, and the place that they occur). Also, objects, events, sequences, goals, and feelings were recorded from interviews and observations. The goal of the descriptive stage was to suggest cultural domains. These could be then formalized by semantic classification such as inclusion, spacial, cause-effect, rational, location, function, means-end, sequence, attribution, etc.

According to ethnographic methodology, each stage in the observation process establishes the foundation for the next stage, allowing for flexibility and changes in the process. The domain analysis isolated specific areas upon which to focus subsequent observations. These were converted to structural questions that could then be asked to the informants. On the basis of the information from the focused observation, a taxonomy was then constructed according to semantic relationships. After identifying some initial taxonomies, detailed interviews and recording of activities were conducted, followed by componential analysis to arrive at a matrix for each domain.

The results of this observation session are still under study, but preliminary results indicate that issues of motivation to learn, maintenance of credibility of a system that might be inaccurate or wrong, timing of advice, and the privacy of the user model must be considered. They must be considered in the design of a system that not only aims to provide active support for the development of CAD skills but will lead to active decision support, symbol retrieval, design case retrieval, standards support, design space navigation, and support for collaborative design in automated environments (Bhavnani, Garrett, Flemming, & Shaw, 1994, in press).

Object Recognition

One of the recurring questions in offering assistance to designers is knowing the intent of the drawing. Just *what* is being drawn. If it is a road, one type of standard is desirable which is much different from the requirement in the layout of a kitchen. A drawing of a building in its concept design stage has a much different level of abstraction and, therefore, needs different functionalities of the CAD system from the construction drawing stage (use of primitive elements vs. standard symbols or dimensions). All widely used CAD systems have stored symbols that have several justifications for their use. It saves time if frequently used objects do not need to be re-drawn each time, using the same symbol aids communication about the object between users in different disciplines, and many times there is extensive non-graphic information attached to the stored symbols. The trend in CAD is toward increasing use of such symbols or "object-orientedness."

As the number of stored objects in the system increases, it becomes harder and harder for users to locate the appropriate symbol. It is often easier for designers to recreate the desired symbol rather than find the standard object and insert it into the drawing. Since the use of standard symbols is very desirable for the reasons mentioned above and their use helps recognize the user's intent as he draws, an object recognition neural network has been developed that could be used either in a search mode (the user begins to sketch the object in a sketch pad) or in a machine initiated mode that "watches" the drawing file and offers an object selection when the drawing approminates a known pattern. The object recognition program, AUGURS, has two modules: The first module employs both temporal and spatial information to determine where the user is currently working and captures the image of that area. The second module, a neural network encoded with geometric knowledge, then performs the classification task on the captured image and proposes to the user symbols resembling the captured image (Shaw, Yang, & Lee, 1993, Shaw, Yang, Garrett, & Bhavnani, 1993, and Yang, & Shaw, 1992).

While recognition of symbols has application for insuring that drawing files meet standards, it has the potential for contributing to user modeling through classifying user intent and stage in design. Changes from one type of object to another (wall layout to plumbing) can be noted and classified according to scales of abstraction and specific detail. The experiments in this project involve optimizing the program performance to extend to a large number of symbols in real time.

Future Plans

Standards Checking

It is difficult to separate higher-order cognitive processes from high quality performance. Perhaps this can be explained by the evidence that experts exhibit detailed and extensive knowledge that allows them to be creative as well as good performers in their domains (Perkins, & Salomon, 1989). The result is that if we foster the development of domain expertise in the use of automated systems we will reap the benefits of both high level solutions and productivity. If we discover that the product of a CAD user is faulty, we can suspect that the processes that are being used are also faulty. This suggests that if we can diagnose the misconceptions or faults as they occur, we may be able to prescribe a remedy and thus improve both the process and the product. Thus, an important signal that assistance is needed is marking the occurrence of a commonly made drawing error or violation of standards at the time it occurs.

We plan to test a standards checking program that will monitor a design file in progress, looking for commonly observed errors. The program will characterize each element creation or insertion in the design file and will simultaneously attempt to offer standard symbol selection through AUGURS. The pilot program will offer non-intrusive informational feedback to the user as suggested by previous research (Lee, 1993).

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In future development of the program, behavior monitoring and mapping to appropriate levels of assistance will be introduced. Questions about the effectiveness of various types of feedback will be asked. Responses other than non-intrusive feedback may be indicated by different user behavior. Such adaptation might include instruction or questioning. Also, we hope to identify other user behaviors that could contribute to our model. From the combination of drawing verification and behavior monitoring, our study of CAD knowledge and user modeling can be made more robust.

User Modeling

The user model represents the system's knowledge about its user which is essential to appropriate adaptation. The types of information that our model will need to acquire include the user's goals and current tasks as well as assessments of skill-level and conceptual understanding. The most important machine learning contribution to the user model is the capacity to "utilize ongoing system-user interaction to update and improve its user model dynamically" (Rendell, 1994).

It is the ability to acquire information automatically that makes a modeling system design feasible in the real world. Collecting information for automated systems is problematic. It is time consuming both to accumulate data and enter it, but most important, its accuracy is always suspect. Even if the logical and user supplied information is correct today, tomorrow's events may make it false. Many times users are not able to respond properly to questioning and their answers may be incorrect or inconsistent causing incorrect behavior of the system. And certainly, users do not like the interruption of queries. Using implicit information collected by machine "observation" of the user's actions allows the user to work without interruption and permits the data to change over time.

While a sufficient background knowledge base is needed to begin the inferencing process, theoretically, incorrect or outdated information can be phased out and more realistic knowledge can assume importance. If a user model presumed that most new CAD users were also new to computers (a fact a few years ago) we would continue to waste time teaching the essentials of DOS. The same will soon be true of Windows and then, perhaps, of keyboards. As we have emphasized before, the requirement for encompassing change is the essence of a successful adaptive system.

Our modeling efforts have been mentioned throughout this paper. In this research, attention will be given to the interaction of the user model, the domain expert, the assistant or advice component, and the system administrator that manages the human-machine environment. Machine learning approaches (Woolf, & Murray, 1993) will be utilized to enhance user models, such as determining in which situations specific corrective strategies work most effectively.

Conclusion

The use of technology will extend and enhance human capacities, but only if people can learn how to use extremely complex systems. CAD is a clear example of the type of complexity and layering of interrelated domains that can be served by automated tools. Traditional training programs that include CAI and classroom treatment are insufficient to cover initial instruction as well as the continuous upgrading necessary. The requirement that learning be continual makes the real world the appropriate classroom. An often unrecognized capability of extremely complex systems is that, through embedded artificial intelligence approaches, they can learn to understand their users and assist human beings when and how they need it. This assistance does not end with skill in mastering procedures but can extend to higher-order thinking and greater creativity. Our research includes ethnographic and learning observations, machine learning algorithms that recognize skill level in users and objects in drawings, and programs that learn to assist CAD users to comply with document standards. The key process is machine learning and modification of user models that will provide the basis for adaptive systems.

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Towards an Adaptive Instruction System for Pre-examination Exercises

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Abstract: A design for an adaptive computer-aided training system is described, consisting of an item bank and a domain independent management system. This paper mainly focuses on the design and implementation of the session management system, responsible for steering the session by selecting items based upon the student's performance. For implementation, a blackboard architecture is used, in which independent knowledge sources communicate via shared memory to reach a solution. There are knowledge sources to select a subject, to select a difficulty level, to select an item, and to maintain the student model. Simulations with a virtual student showed promising results. In the near future test sessions will be held on the first-year Electronics course.

Introduction

It is well known that an important part of learning an engineering subject is solving problems that illustrate the principles. Honderd & Jongind (1990) stressed the importance of active participation, i.e. that the students try to solve the problems themselves. If the number of students per training session becomes too large, the students tend to merely write down the solutions the instructor gives on the blackboard. However, especially in the first two years of the education for Electrical Engineer, the courses are massive; there are not enough human resources for a more personal approach.

A computer can offer a solution for this dilemma. If a computer program can handle students with "standard" problems, the instructors will be available for students with unusual problems. With a computer based system, the students can practice whenever they want. Another advantage is that students seem less reluctant in approaching a computer than in approaching a human instructor (Pullen & Mercer, 1988). And last but not least, computing power allows simulations and complex calculations to be performed.

On the other hand, practice has shown that successful CAI systems are not easy to build. Too often systems become so complicated that they are only applicable to small domains, hard to maintain or very domain dependent. This research is focused on implementation of a domain independent adaptive system with a conceptually simple structure.

Aims and requirements

The main aims of developing the system are twofold:

- enable the students to perform exercises as often as they wish and at hours they choose
- free the instructors from routine work.

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The requirements can be divided into four main parts:

Maintainability: An important aim is that the teacher or instructor must be able to implement or change the problems by himself/herself in an easy way. It should take little effort to keep the system running. Further, since there are a lot of problem types and every teacher has his own preferences, there should not be a restriction to a single problem implementation tool.

Domain independency: Because of the intended use for various courses, the system should be as domain independent as possible. This means that the domain dependent information must be kept separately.

Usage of graphics and simulations: With engineering courses, graphics are often used to clarify subjects. In control theory for example, time- and frequency responses, block diagrams, and pole/zero configurations are used intensively. Therefore, the instruction system must be able to display graphics and perform simulations. Since good simulation software is available already, usage of existing software is desirable.

Tailoring to individual students: To be able to handle students in various preparation phases, the system should adapt to the level of the student. This means that the system must support various levels of difficulty. The student should get problems that are not too hard and not too easy. Also, the problems should support variation of parameters to be able to create a different instances from the same problem. Accuracy of the adaptation is less important in a training environment than it is with tests; the primary goal in training is to offer practice while the primary goal in testing is to give an objective and fair measure of the student's proficiency level.

System architecture

In view of the requirement of domain independence, the concept of item banking is used. An item bank is a data base containing items and information about the items. Each item represents a specific problem. An item manager provides an environment for creation and maintenance of items and item bank management. A session manager uses the item bank to create training sessions for the students.

One of the drawbacks of the currently known item banking systems is that item constructors are limited to the environment the system poses onto them. The experimental system Items-D (Jansen et al., 1991) does not provide an environment for item creation itself, but relies on external environments, allowing the item constructors more freedom. Unfortunately, Items-D is nonadaptive; all sessions have to be specified beforehand. The system described here will use the Items-D method for item implementation and item bank management, but will provide an adaptive session manager. A description of the item bank structure and the session manager architecture will be described in the next sections.

The item bank

The item bank is the domain dependent part of the system. Items are usually problems, including execution specifications and possible data files, and information about the problem. This information consists of, for example, the subject it is about, the difficulty, the variable parameter information and the methods to calculate the answers. In addition, the item bank contains a list of subjects that are involved with their mutual relations (prerequisites, curricular order etc.).

The items must be able to read and create data files containing parameters, answers and other relevant information like the maximal number of attempts and whether or not help is available. The interface definition from Items-D is adopted, making it possible to use the items also in standard Items-D. This method uses ASCII files for data transport between the management system and the item. Items can be implemented in any programming environment as long as it is possible to generate and read data files, and the environment allows stand alone execution of the application.

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The session manager

In the aims it was stated that the system must adapt its training at the student's course level. The task of the session manager can be divided into several subtasks:

- select subject
- select difficulty
- select item
- show item and get answer(s)
- update student model

A control mechanism will have to take care of the initial choices, stop criteria and the activation of subtasks. These subtasks need shared information like the current subject, difficulty and the estimation of the student level for the current subject. Further, the order of execution of the tasks is not explicitly known in advance. It is possible, for example, that the difficulty selector concludes that it is better to change subjects, in which case a new subject (and for that subject a new difficulty) must be selected before an item can be chosen. In this situation a blackboard architecture (Jagannathan et al., 1989) seems a suitable solution.

The architecture is best described by a metaphore. Imagine a number of independent experts cooperating to solve a problem. The experts have expertise on different fields relevant to the problem. They use a blackboard to write down the goals and the intermediate results. A chairman can be assigned the job of keeping structure in the solving process (see figure 1). An expert informs the chairman if the information on the blackboard gives possibilities for extraction of new results. The chairman allows the expert that has the best chance of coming closer to the desired goal to use his expertise.

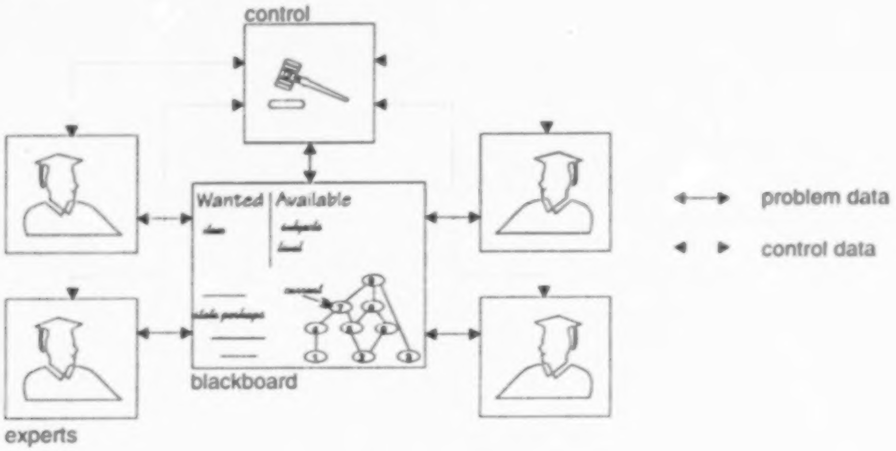

Figure 1: The blackboard model

Applied to our problem of giving proper training to the student, the final goal is that the student has a good impression about his abilities to pass the exam. The subtasks specified above form the experts. Each expert or knowledge source (KS) has an activation record (KSAR) which holds preconditions for activation and possible postconditions. For example, a KS for selection of an item has as preconditions the availability of subject and difficulty, and as postcondition the availability of an item. The analogon of the chairman is a control procedure; the blackboard is a collection of shared data.

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The adaptation mechanism

The system adapts on two entities: the current subject and the current difficulty level. This section explains the idea behind the adaptation processes in more detail.

Subject adaptation

A structure called a *subject lattice* is used to find a suitable subject. This structure specifies the relations between all relevant subjects of a course. A prerequisite link from subject A to subject B shows that the student should master subject B sufficiently before before subject A can be selected. Further, a curricular order can be specified showing the "ideal" order of the subjects. An example is shown in figure 2. Arrows denote prerequisite relations; the numbers show the curricular order.

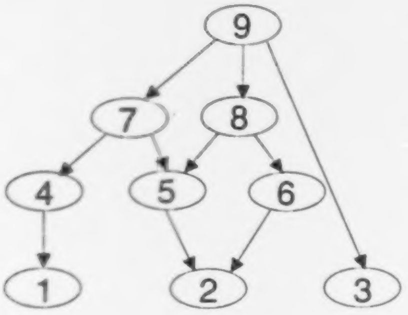


Figure 2: Example of a subject lattice

Difficulty level adaptation

The difficulty level adaptation uses item characteristic curves (ICC's), originating from the item response theory (IRT). Before the adaptation method is explained, a brief description of the item response theory will be given.

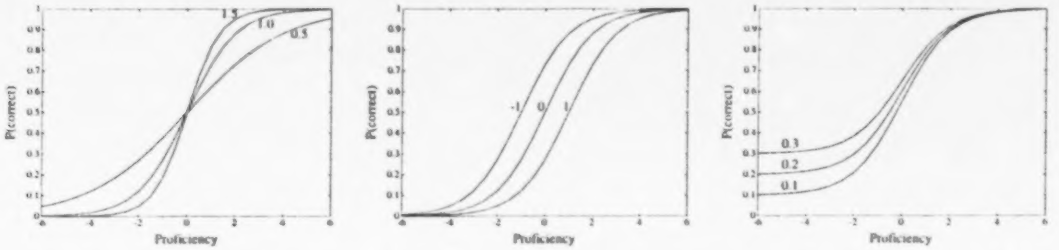
According to Hambleton (1989), "An item response model specifies a relationship between the *observable* examinee item performance (correct or incorrect responses) and the *unobservable* abilities assumed to underly performance on the test. This relationship is called an Item Characteristic Curve". The ICC is described by a mathematical function. The value of an ICC for item i at ability level θ, denoted $P_i(\theta)$, can be viewed as the probability associated with a randomly selected examinee at ability level θ, answering i correctly. An often used model is the 3 parameter logistic model (3-PL), defined by

$$P_i(\theta) = c_i + \frac{1 - c_i}{1 + e^{a_i(b_i - \theta)}} \qquad (1)$$

in which the three parameters are the item difficulty b_i, the item discrimination parameter a_i and the pseudochance level c_i. The influence of these parameters is shown in figure 3.

For proficiency estimation, the likelihood function L is used. This function describes the likelihood that a student with proficiency θ would give the response pattern x (in which 0 = incorrect, 1 = correct).

$$L(\theta|x) = \prod_i P_i(\theta)^{x_i} \cdot \{1 - P_i(\theta)\}^{1-x_i} \qquad (2)$$



(a)
Varying a (b=0, c=0)

(b)
Varying b (a=1, c=0)

(c)
Varying c (a=1, b=0)

Figure 3: Examples of Item Characteristic Curves with 3-PL

In words, each term in the product is an ICC if the corresponding answer was correct and the negation of the ICC (1 - ICC) if the answer was incorrect. If the item parameters and the item scores are known, the value of the likelihood function only depends on the unknown variable θ. By maximizing the likelihood function with respect to θ, the maximum likelihood estimate is found. For more detailed information about the item response theory and adaptive testing see Hambleton (1989) or Wainer (1990).

The IRT method has the advantage of making optimal use of available information, but it is computationally very intensive. Further it depends on unidimensionality, i.e. the same trait is assumed to underly all items. With various subjects, our application clearly does not satisfy this condition. Extension to multidimensionality would require an even greater computing power. And does the method take into account that the student learns from previous items? With tests this learning effect is probably not so high, but with instruction you *want* the students to improve, so the student's level will not remain constant. Another point is that IRT selects a next item that gives the most information. But from a pedagogical point of view, this does not always have to be the best item. In instruction, one would probably prefer a gradual increase in difficulty above a switch from very easy to very difficult as could easily occur in the standard IRT after asking one item: if the first item is simple and is answered correctly, the most likely level is +infinity, yielding the most difficult item available.

The method proposed here intends to select an appropriate difficulty level that is less computationally burdensome (but also less accurate). The new difficulty level is calculated as follows:

$$b = \mathit{scale} \left\{ P_i^{-1} \left[(1 - \beta_C)^{x_i} \cdot {\beta_I}^{1 - x_i} \right] \right\} \tag{3}$$

The function *scale* transforms the argument from the interval $(-\infty,\infty)$ to the interval $[0,1]$. P_i^{-1} is the inverse function of P_i. The β factors describe the speed of adaptation; β_C is used with correct answers and β_I with incorrect answers. If they are close to zero, the adaptation will be abrupt; close to 0.5 there will not be any adaptation at all. Empirically found reasonable values are between 0.01 and 0.2, depending on the quality if the items.

With a correct answer to item i $(x_i = 1)$, the method takes the level that gives a $1 - \beta_C$ chance of success on i. Similarly, with an incorrect item, that level is taken for which the probability of correct response is β_I. If a guessing floor c is used in the ICC, β_I must be greater than the largest c because the minimal probability is c.

The advantage of this method is that it needs only the current item's characteristic curve and can be computed very fast without the need of numerical methods. Another point is that earlier results on the subject are forgotten more quickly. This means that if a student "sees the light" on a topic, his past won't hunt him very much.

Session manager implementation

The blackboard

The information on the blackboard can be divided into several parts: the domain model blackboard, the student model blackboard, the steering blackboard and the control blackboard.

The **domain model blackboard** contains the previously described subject lattice. The subject contents are not specified in the domain model blackboard; these remain within the items. The item bank is also not part of the blackboard, as only the item selector needs access to it. The information of the current item however, if any, is available on the blackboard.

The **student model blackboard** contains a reflection of the domain model. Per subject it contains an estimated proficiency level θ (with a moving average $\hat{\theta}$), and a notation for the student's assumed competence, with possible values *Unknown*, *Perhaps* acquired, *Possibly* acquired and *Strong*. This notation was introduced by Lesgold e.a. (1989).

The **steering blackboard** contains pedagogical information like the criteria the student must meet to qualify for having "sufficiently mastered" a subject (for example, the status is at least *Probably*). Further the speed of the adaptation process and the maximal number of items on one subject are available. At the moment this is a write-once and then read-only blackboard, but in the future a monitoring KS could be allowed to adjust the parameters.

The **control blackboard** contains information about wanted and available (intermediate) results. This is used by the knowledge sources to check if both their preconditions are available and their postconditions are wanted. It consists of two flag pools: a "wanted" pool with results that, if obtained, can lead to a new solution, and an "available" pool containing already obtained results. KS'es are free to examine and change these pools, thus possibly influencing control decisions. For example, if the subject model updater notices that the proficiency level on another subject decreases because of the item result, it can remove "subject" from the available pool. Then, before a next item can be selected, a new subject will have to be chosen. The control mechanism is also able to update the control blackboard. If no experts are triggered by the available information, it looks for unsatisfied KS preconditions and posts these as "wanted".

The knowledge sources

The **subject KS** takes care of subject adaptation. First, it examines the lattice for subjects with state *Perhaps*. This is a nonstable state, showing that more information is needed to be able to decide whether or not the student's knowledge is sufficient. If there are no subjects with state *Perhaps*, focus is put on subjects without prerequisites or with sufficient student mastery on the prerequisites. If this still does not give a result, then the reinforcement technique is applied: subjects with state *Probably* are made candidates. Normally this means that the subject lattice is traversed again in curricular order. If the selector still was not able to select a subject now, it signals the control blackboard that the subject lattice is exhausted. An extra parameter taken into account is the number of items asked on a subject. If a student's state on some subject is *Unknown* after 5 relevant items, there is more reason to doubt that student's knowledge than after one item. Naturally, other strategies could also be applied, for example first raising a status to *Strong* before selecting a new subject. However, this has the risk that the students stay with a subject for a long time and get bored.

The **difficulty level KS** selects a new difficulty with the method described in section "Difficulty level adaptation" above. Simulations with virtual students of various proficiency levels have shown that this method gives the desired adaptation to performance. This also holds if the difficulty level is a discrete variable with a small number of possible values (e.g., 10) as will be the case in reality: for teacher convenience the difficulty level will be described in fuzzy terms like "hard", "easy", etc.

The **item selector KS** searches the item corresponding best to the currently specified subject and difficulty level, taking into account restrictions like "don't give the same item twice in one session". Per item (problem) the main

Essenius, R.P. (1994). Towards an adaptive instruction system for pre-examination exercises. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 157-164). Nashville, Tennessee: Omni Press.

subject involved and possible influencing sub-subjects are recorded. Each item subject is labelled with parameters characterising an ICC (difficulty level, discrimination value, guessing correction). If an item is selected, the characteristics (subject records with ICCs) are put on the blackboard.

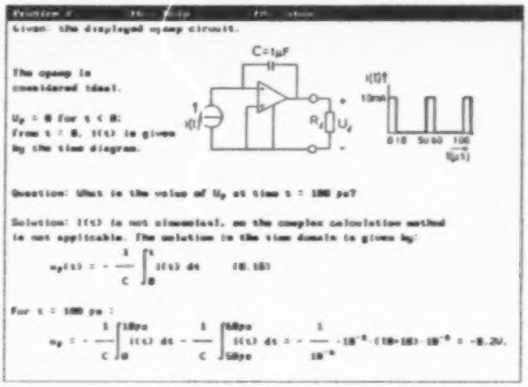
The **item presenting KS** presents an item to the student. It runs the executable of the item, after preparing the necessary information, Items-D compatible data files, containing parameters, answers and possibly various other information like number of tries, additional short hints, rules for grading the item, etc. These are all available in the item specifications. The executed item returns a data file containing the result (given answer(s), obtained score, number of retries) which is interpreted by the item presenter. The important results are reported on the blackboard.

The **student model KS** updates the "shown levels" (the levels at which the student has shown to answer an item correctly) and, if needed, the state variables of all involved subjects. A state change from *Unknown* to *Perhaps* occurs if at least one item of at least a minimal level is answered correctly. A state change to *Strong* occurs if the moving average over 3 items is above a maximal level. Then, if the level is above a medium level, the state becomes *Probably*; if the level is under that medium level, it becomes *Perhaps*. The student model updater also signals the control blackboard if a relevant (i.e. subject changing) state change has occurred.

Item implementation

A number of items has been realised for introductory courses on Control Theory and on Electronics, using the authoring system Taiga (Educational Centre, 1987) with the toolboxes I^2T and *the Control Toolbox*, developed at the laboratory (Essenius, 1992). These toolboxes process interface files and offer easy methods to display several graph types like time- and frequency responses, pole-zero configurations, flow diagrams and drawings made in an external drawing program.

An item acceptance test in the fall of 1993 showed that most of the students appreciated the computer training. However, the item layout in Taiga needs special consideration. Because of the limited display facilities (maximal text size is 20 lines with 80 characters 20 lines) the display tends to become obscure. Figure 4a shows an item implemented in Taiga. At the moment of the screen capture the solution is shown.



Given: the displayed opamp circuit.

The opamp is considered ideal.

$U_o = 0$ for $t < 0$:
From $t = 0$, $i(t)$ is given by the time diagram.

Question: What is the value of U_o at time $t = 100$ μs?

Solution: $i(t)$ is not sinusoidal, so the complex calculation method is not applicable. The solution in the time domain is given by:

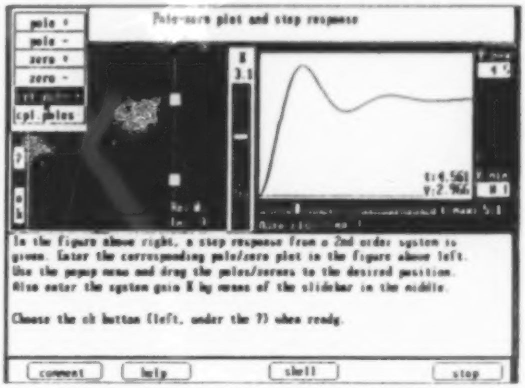
$$u_o(t) = -\frac{1}{C}\int_0^t i(t)\,dt \qquad (8.18)$$

For $t = 100$ μs :

$$u_o = -\frac{1}{C}\int_0^{10\mu s} i(t)\,dt - \frac{1}{C}\int_{50\mu s}^{60\mu s} i(t)\,dt = -\frac{1}{10^{-6}}\cdot 10^{-2}\cdot(10+10)\cdot 10^{-6} = -0.2V.$$

(a)

a Taiga item



In the figure above right, a step response from a 2nd order system is given. Enter the corresponding pole/zero plot in the figure above left. Use the popup menu and drag the poles/zeroes to the desired position. Also enter the system gain K by means of the slidebar in the middle.

Choose the ok button (left, under the ?) when ready.

(b)

a Turbo Pascal 5.5 item

Figure 4: Examples of implemented items

With Inigo (Educational Centre, 1992), the successor of Taiga, this problem was solved by using the environment MS-Windows. Taking into consideration other advantages of MS-Windows in comparison to MS-DOS, it was

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decided to "upgrade" the items into Inigo. The interface file processor has been ported to Inigo and currently the Control Toolbox is being ported.

Some items on Control Theory, involving simulations, were made using Turbo Pascal 5.5. These items use the transformation and identification package TRIP inline to calculate responses. With this technique, it is possible to play "what if" games with the student. For example, figure 4b shows a problem in which the student is asked to enter a pole-zero plot corresponding to a given time response. If an incorrect answer is given, the item can show the time response that would be obtained with the answer. More information is given in Essenius et al. (1993).

Future research

It is considered important that the student has some influence on the decision process. Student enquiries also supported this viewpoint. However, learner control often does not give satisfactory results (Chung & Reigeluth, 1992). Weaker students tend to practice less than they need and better students sometimes practice much more than they need, just to be certain. The possibility for computer guidance, in which the system offers a number of choices, suggests one and leaves the final decision to the student, could offer an alternative to strict computer control on one hand and strict learner control on the other hand. The possibilities to implement this are now investigated. At the moment, the final parts of the session manager (the item displayer and some parts of the item selector) are being implemented. In the end of March a first test (under MS-DOS, still with Taiga items) will be organised with volunteering students. After evaluation of the test and a teacher enquiry, a larger scale test under MS-Windows, also with Inigo items) will be performed. The first release of the system is planned in October 1994.

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Deciding What to Remediate in an Intelligent Tutoring System: a Practical Approach

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Abstract: An Intelligent Tutorial System (ITS) provides adaptive remedial tuition by making inferences about the nature of the student's misconceptions, typically by maintaining a model of the student's knowledge and comparing it with an ideal model. Such models are complex. *ICATS* is an ITS which interfaces with almost any Authoring System, to provide an adaptive environment based on a Course Hierarchy Network (CHN). The CHN is a directed graph representing the dependencies between the subtopics constituting a lesson. *ICATS* also maintains a Student Progress Record (SPR) which tracks the student's path through the CHN. The nodes of the SPR constitute a subset of the nodes of the CHN, but contain different information. This paper briefly describes *ICATS*, and then discusses ways in which the SPR may be used to diagnose a student's weaknesses, and provide remedial tuition. The paper demonstrates the possibility of achieving adaptive behaviour in a CAL system, without complex knowledge representations.

Introduction

Much current research and development in Intelligent Tutoring systems (ITS's) is based on the use of many complex representations, such as: the knowledge domain, models of a student's knowledge, representation and classification of student errors etc. The "Lisp Tutor" (Reiser et al., 1985), and "PROUST" (Johnson W.L et al., 1987; Littman et al., 1988) are examples of this type of system. A number of other examples are discussed in (VanLehn, 1988).

Such efforts are highly desirable, and indeed necessary, if we are to achieve ITSs that approach the usefulness and adaptability of human tutors.

Meanwhile there is much useful work that can be done using cruder techniques that nevertheless make Tutorial Systems more intelligent than conventional Computer-Assisted Learning Systems. This paper describes such a system: *ICATS* (Intelligent Computer-Assisted Tutorial System).

Overview of *ICATS*

ICATS is a development of an earlier proposed system (Harris, 1985). *ICATS* uses a directed graph, the Course Hierarchy Network (CHN), to represent, crudely, the knowledge of the domain, as well as a crude model of the student's knowledge, the Student Progress Record, to determine what remediation should be applied, and when.

ICATS allows the courseware author to define the CHN corresponding to the prerequisite structure of the topics making up a lesson. Each topic can then be authored with an appropriate authoring system. *ICATS* links the authored segments to the nodes of the CHN. The author supplies information about pass-mark values, and any other supplementary information. More details about the CHN are discussed below.

The use of a graph to define the structure of lesson material has been discussed in (Ferraris et al., 1984) where a Petri net (Peterson J.L, 1981) description of the lesson is advocated. However, unlike *ICATS*,

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Ferraris's system does not suggest using the net to control automatically the sequence of CAL material, or to determine the need for remediation and what remedial material to apply. A further difference is that Ferraris's net contains loops, whereas the *ICATS* net does not. *ICATS* assumes that if a given item of teaching material depends upon knowledge of earlier material, then no earlier material can depend, in turn, on it. This principle rules out loops.

Moreover, the Petri net must be interpreted as a dynamic representation of the CAL material - hence repetition of earlier material must be represented by a loop. The *ICATS* net represents the static dependencies of the material, and the *ICATS* inferencing and control mechanisms activate forward and backward movement through the net.

The Course Hierarchy Network (CHN)

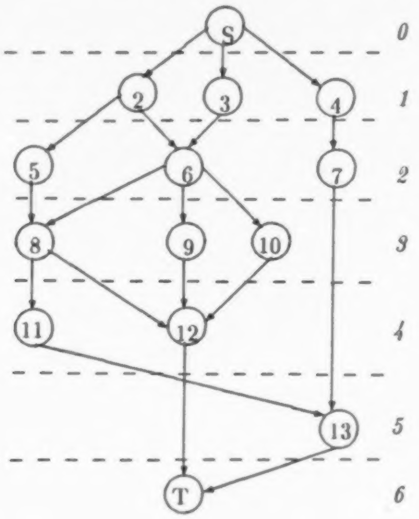
The purpose of the CHN (**Fig.1**) is to represent the hierarchical, or prerequisite structure of the CAL course. Each node (**Fig.2**) in the CHN represents a *segment* (see below) of CAL material.

The segment

A segment would, typically, be a screenful of orthodox CAL material such as would be produced by any decent Authoring System. The node might include an executable CAL filename, or a pointer to executable CAL code, or a procedure that invokes a CAL segment: the implementation details are not important. For the purposes of this discussion assume that a node is an abstract entity that, somehow, under a set of conditions to be explained below, triggers a CAL segment.

The node

Each node, except the start node, has a non-empty set of immediate "parents". For any given node its parent nodes represent the CAL segments whose knowledge content is assumed by the given node's CAL segment. Parents of a given node can be associated logically by AND or OR relationships.[1]



Number in node: identifier *i*; italicised number: depth *g* of node. **S**: starting node; **T**: terminal node

Figure 1. A simplified, but typically structured, CHN

If each CAL segment is "fine-grained" - i.e is confined to imparting a very small piece of knowledge - the CHN would correspond, loosely, with a representation of the knowledge domain. However, since

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[1] NOT is unlikely to be relevant for CAL applications, but perhaps should be included for completeness.

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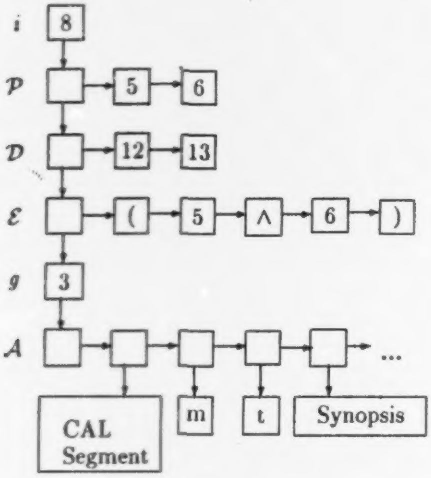
the CHN is a directed graph without loops, it would not be exactly equivalent to a representation where knowledge-elements were linked associatively or semantically. In fact the CHN represents *meta-knowledge* of the knowledge domain. Strictly speaking, the CHN represents the *course designer's* knowledge of the dependencies between the segments.

In addition to the segment information, each node in the **CHN** is associated with information that is used to determine the attainment-level of a student when s/he interacts with the associated segment. Again, the actual implementation details are of no concern: this additional information may take the form of node-local and/or system-global rules applied to the actual student input, or to data supplied by the segment, such as the scoring methods to be used for the segment.

Other segment-related information may also be attached to the node, such as: relevant remedial material, reference material, hints, and so on. In the interests of separating abstract representations from CAL-specific data, the associated information should take the form of pointers to, or indirect invocations of, rather than direct calls to such material.



The number in *i* is the node identifier
The number in *g* is the depth
The numbers in the other boxes are pointers to parent or child nodes
Typical node structure
Figure 2

A Practical Example

The *ICATS* CHN

The following describes each node in the **CHN**, in the *ICATS* application.

The *ICATS* Node

Any node $\mathcal{N}$ is a 6-tuple, such that:
$\mathcal{N}=\{i,g,\mathcal{P},\mathcal{D},\mathcal{E},\mathcal{A}\}$
where:
$\mathcal{P}$ is the set of immediate parents of $\mathcal{N}$;
$\mathcal{D}$ is the set of child nodes of $\mathcal{N}$;

$\mathcal{E}$ is a boolean expression, representing the prerequisite relationships for $\mathcal{N}$, such that each element of $\mathcal{P}$ appears at least once in $\mathcal{E}$;[2]
i uniquely identifies this node;
g is the node-depth; i.e the number of nodes in the longest direct path from the start node to $\mathcal{N}$;[3]
$\mathcal{A}$ represents all information associated with N;
for *ICATS*, $\mathcal{A}$ is a triple:
$\mathcal{A}=\{s,m,t\}$
where
s identifies the associated CAL segment;
m represents a pass-mark for the associated segment;
t represents a "threshold" for the associated segment;
let $\mathbf{v}$ be the mark obtained by the student when the segment was attempted:
then
$\mathbf{v}<m$ represents failure;
$m\leq\mathbf{v}<t$ represents a "weak" pass;
$\mathbf{v}\geq t$ represents a "good" pass.

Implementation Considerations

In *ICATS*, the node items are held as pointers to data or to lists, or to procedures, so that "raw" data is kept separate and the **CHN** remains an abstract representation at a very general level.

The *ICATS* Student Progress Record (SPR)

Each student has an **SPR**. The **SPR** is a set of data-records, ordered in accordance with the order in which the student tackled the CAL segments.

The SPR Data-record

Each data-record d in the **SPR** is a tuple:
$d=\{s,\mathbf{v}\}$
where s and $\mathbf{v}$ have the meanings described in *The ICATS Node*, above.

Strategies for Remediation

There are several distinct strategies for identifying the origins of failure and thereby determining what remediation should be adopted. Each strategy uses the information in the **CHN** and **SPR**. Generally, each strategy assumes that the cause of failure (in a segment associated with a node) can be attributed to weakness in one or more nodes along one or more of the paths that led to the failed node. However, each strategy uses the information differently. these strategies are discussed below.

The Maximum Depth Principle

ICATS operates on the *Maximum Depth Principle*. That is, the system always delivers, when possible, the deepest CAL segment that the student is qualified to attempt. Depth is measured by g (see above).

This principle and the strategies for remediation (see below) are based on the intuitive beliefs and experience of the author, rather than on any established pedagogical principles.

Justification of the Maximum Depth Principle

It is in the interests of the student to keep her/him progressing as deeply into the material as possible. This helps to maintain interest, "stretch" the student, and to develop a deeper understanding of the subject,

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[2] The presence of $\mathcal{E}$ makes the need for $\mathcal{P}$ redundant. It is retained for "housekeeping" purposes.

[3] g is used with the Maximum Depth Principle; see below

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so that, if remedial back-tracking is required, s/he can re-attempt earlier material with greater confidence.

Definitions and Notation

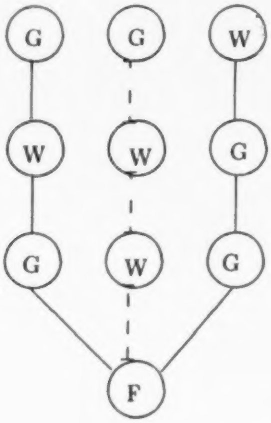
$\mathcal{N}$ is any node in the Student Record which is not a weak node (see below) and is not a failed node.
$\mathcal{F}$ is any failed node in the Student Record.

$\mathcal{N} \rightarrow \mathcal{F}$ represents any path from $\mathcal{N}$ to $\mathcal{F}$, consisting of just those nodes in the Student Record which were traversed as the student progressed from $\mathcal{N}$ to $\mathcal{F}$, inclusive of $\mathcal{N}$ and $\mathcal{F}$.

There may be several distinct paths $\mathcal{N} \rightarrow \mathcal{F}$; that is, several paths $\mathcal{N} \rightarrow \mathcal{F}$ containing nodes associated with segments "passed" by the student, which converge on $\mathcal{F}$.

General weak path. (GWP)

A path is a **GWP** iff it is either a **CWP** (see below) or an **AWP** (see below).



G: "good" pass; W: "weak" pass; F: "fail"; dashed line: *weak* path
Figure 3

Contiguous weak path. (CWP)

$\mathcal{N} \rightarrow \mathcal{F}$ is **CWP** (Fig. 3) iff all nodes in $\mathcal{N} \rightarrow \mathcal{F}$ other than $\mathcal{N}$ and $\mathcal{F}$ are weak nodes.

Absolute weak path. (AWP)

A path is **AWP** iff it conforms in every respect to a **CWP**, except that there is no node in the Student Progress Record that corresponds to N.

In other words, an **AWP** is a path from the start node $\mathcal{S}$, to $\mathcal{F}$, in which all nodes (including $\mathcal{S}$) up to but excluding the immediate parent of $\mathcal{F}$ are weak nodes.

Weak node

Any node with associated score **v** in the **SPR**, where $m \leq \mathbf{v} < t$ (see above), is a weak node.

Earliest weak ancestor. (EWA)

For any **GWP**, the weak node nearest to $\mathcal{S}$ (or $\mathcal{S}$ itself, in the case of **AWP**) is called the **EWA**

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of $\mathcal{F}$.

Latest weak ancestor. (LWA)

For any **GWP** , the immediate parent of $\mathcal{F}$ is called the **LWA**.

Mutual weak ancestor. (MWA)

For all **GWP's** in the Student Record, any node which is common to two or more such **GWP's** is called an **MWA**.

Convergent Mutual Weak Ancestor. (CMWA)

For all **GWP's** which converge on a given $\mathcal{F}$, any node which is common to two or more such **GWP's** is called a **CMWA**.

Degree of mutuality

The degree of mutuality, of any **MWA** or **CMWA** is measured by the number of **GWP's** that share the **MWA** or **CMWA**.

Possible Remediation Strategies

EWA Strategy

1. Find the earliest failed node.
2. Find any **GWP** for the failed node, and its associated **EWA**.
3. Re-issue the material (original, or, if present, remedial) associated with the **EWA**.

EWA : Justification

The **GWP** probably led to the failure in question (the earliest failed node).

If the **EWA** can be successfully tackled by the student, there is some hope that each succeeding weak node in the **GWP** can then be tackled successfully, since each weak node is dependent on its weak predecessor.

Hence the earliest failed node should be taken first, since subsequent work by the student will often lead to her/his being able to grasp earlier, usually more elementary, points, with greater confidence.

LWA Strategy

Essentially the same as the **EWA** Strategy, except that the **LWA** is sought.

LWA : Justification

Subsequent work by the student probably boosts her/his confidence and general grasp of the subject, so that s/he will probably succeed with the **LWA** without having to work through the entire **GWP**.

However, if the student fails the **LWA** again, this strategy will loop infinitely round the **LWA**, unless the fact of second-try failure is noted (see Failure Count, below) and used so that next time the weak parent of the **LWA** is tried, and so on back up the **GWP**. This is a more complex strategy than the **EWA** Strategy.

MWA Strategy

All **MWA**'s derivable from the Student Record are noted, with their degrees of mutuality (see above).

Harris, M. (1994). Deciding what to remediate in an intelligent tutoring system: a practical approach. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 165-172). Nashville, Tennessee: Omni Press.

The MWA with the highest degree of mutuality is issued.

MWA : Justification

If a weak node is common to more than one failure, it seems likely that it is responsible for all those failures, or, at least, has contributed substantially to them.

Moreover, the one with the highest degree of mutuality is probably the most culpable.

CMWA Strategy

As for **MWA** , but with **CMWA**'s.

CMWA : Justification

The justification for this strategy is similar to, but stronger than that given for **MWA**.

Combination Strategy

Combine the above strategies. For example, if the **MWA** Strategy still leads to failure, try the **LWA** Strategy, and if this is unsuccessful, try the **EWA** Strategy.

This will require maintenance of a record, within the **SPR**, of what strategies have been used with each failed node.

Alternatively, the strategy could be tied to a *Failure Count* (see below), so that, as the value of the count changes, another strategy could be tried.

Failure Count

Each failed node in the Student Record could carry an associated failure count, indicating how many times the given node was failed.

The system could limit the number of failures allowed (perhaps as a teacher-supplied option). When the number is exceeded, it would indicate to the student what the areas of weakness were (e.g: show the synopses associated with each node in the given **GWP**), and what reading is needed to remedy the weakness.

Conclusion

This paper has attempted to demonstrate that strategies exist that would permit the use of conventional CAL material within an ITS, such that reasonable inferences may be made which identify where remediation should occur, without a complex knowledge representation.

Harris, M. (1994). Deciding what to remediate in an intelligent tutoring system: a practical approach. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 165-172). Nashville, Tennessee: Omni Press.

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Boulet, M.M. (1994). Adding advice to a CASE tool. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 173-177). Nashville, Tennessee: Omni Press.

Adding advice to a CASE tool

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Abstract: Among the mandatory courses of the undergraduate curriculum in Computer Science at Université Laval, there is *Systems analysis and design*. Conceptual database modeling, and more specifically Entity-Relationship approach (Chen, 1976), is an important topic covered in that course. The production of an Entity-Relationship Diagram (ERD) that actually represents the access paths to data needed by an enterprise, is a very complex transfer task. Leshin, Pollock, and Reigeluth (1992) state that transfer tasks have great variation from one performance to another. These tasks cannot easily be broken down into steps, because each time the task is performed, the learner generates a procedure which is appropriate to that particular set of circumstances.

Introduction

Systems analysis and design is a mandatory course of the undergraduate curriculum in Computer Science at Université Laval. An important topic is modeling data with Entity-Relationship Diagrams (ERD).

Data modeling is not easy. The learner's task in data modeling is to figure out what types of data underlie the business function under study. The learner must also capture a replica of that structure. Each business function is different. Leshin, Pollock, and Reigeluth (1992) stated that: "Transfer tasks have great variation from one performance to another" (p.49); "... cannot easily be broken down into steps, because the activity varies each time the task is performed" (p.82). Elaborating an ERD corresponds to a transfer task.

The *Systems analysis and design* course has two parts. Concepts, principles, and rules are taught during a theoretical part. Learners transfer this knowledge during a practical part; they have to resolve cases. The COnceptual DAtabase Modeling Advisor (CODAMA) was developed to further the transfer of knowledge during the practical part.

Advisor system

An intelligent advisor system is an adaptive system aimed to intervene when an individual is performing a complex transfer task (Boulet, 1992). This instructional technology takes place after the initial learning of concepts, principles, and rules. It is an environment of help utterly linked to the use of what has been learned. Users think and integrate several kinds of knowledge to find the "right" way to solve a complex problem.

An important aspect to take into account is the identification of strategies and tactics the advisor uses to provide advice, guidance, hints, explanations, and to answer questions. The main purpose is to provide an environment tailored to the user's needs and goals. An advisor system helps either to relate theory to practice, or to develop more effective problem-solving strategies, or both.

CODAMA

Students enrolled in *Systems design and analysis* course have weak knowledge of the domain and no practical experience. They draw their ERD with a CASE tool (Computer Aided Software Engineering, Figure 1). CODAMA is interfaced to that CASE tool. The set up of CODAMA adds an option within the menu bar: the ADVISOR option. A learner produced a part of an ERD. She or he created the entities COURSE, PROGRAM, ADDRESS, STUDENT, and PROFESSOR, and the relationships ENROLLS, GIVES, and HAS. There are attributes not yet associated. Some cardinalities was set. The learner can call CODAMA to make sure that this part of the ERD actually represents the business function.

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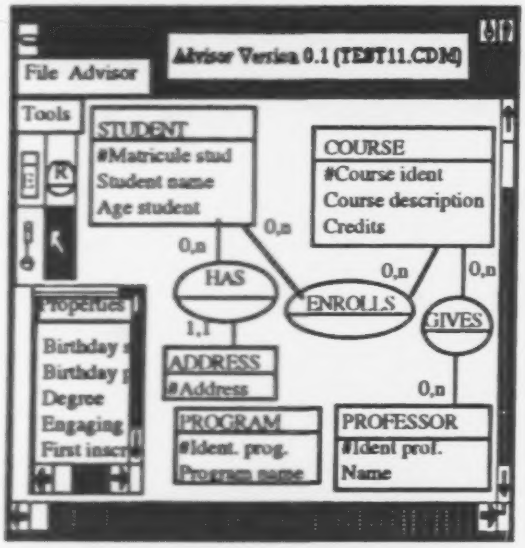
Advisor Version 0.1 (TEST11.CDM)
File Advisor
Tools
STUDENT
#Matricule stud
Student name
Age student
COURSE
#Course ident
Course description
Credits
0,n
0,n
HAS
ENROLLS
0,n
0,n
GIVES
1,1
ADDRESS
#Address
0,n
Properties
Birthday s
Birthday p
Degree
Engaging
First inscr
PROGRAM
#Ident. prog.
Program name
PROFESSOR
#Ident prof.
Name

Figure 1. CASE tool window.

Figure 2 shows the menu displayed after a learner told CODAMA that she or he wanted explanations about cardinalities of the relationship ENROLLS.

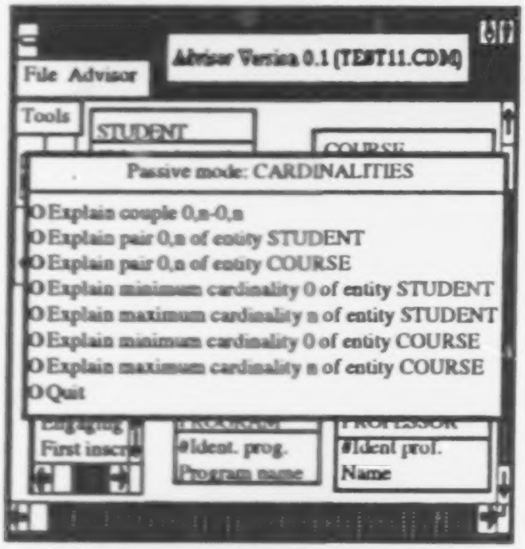
Advisor Version 0.1 (TEST11.CDM)
File Advisor
Tools
STUDENT
COURSE
Passive mode: CARDINALITIES
○ Explain couple 0,n-0,n
○ Explain pair 0,n of entity STUDENT
○ Explain pair 0,n of entity COURSE
○ Explain minimum cardinality 0 of entity STUDENT
○ Explain maximum cardinality n of entity STUDENT
○ Explain minimum cardinality 0 of entity COURSE
○ Explain maximum cardinality n of entity COURSE
○ Quit
Engaging
First inscr
PROGRAM
#Ident. prog.
Program name
PROFESSOR
#Ident prof.
Name

Figure 2. Example of menu.

Suppose the learner selects *Explain minimum cardinality 0 of the entity STUDENT*. The explanation presented at Figure 3 will be superimposed. There are underlined words. Two of them refer to prerequisites: *Entity* and *relationship*. That means an individual cannot understand what is the meaning of this explanation if she or he does not know or does not remember what is an entity or a relationship. By clicking on one of those underlined words, the learner can have the corresponding explanation (or a set of explanations because there are other underlined words within other explanations). This access to prerequisites was set to help recalling one or another concept in the short term memory.

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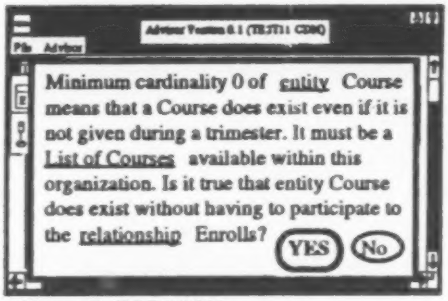

Minimum cardinality 0 of entity Course means that a Course does exist even if it is not given during a trimester. It must be a List of Courses available within this organization. Is it true that entity Course does exist without having to participate to the relationship Enrolls?

Figure 3. CODAMA's answer.

The learner can also see and use a network. A part of the network is presented at Figure 4.

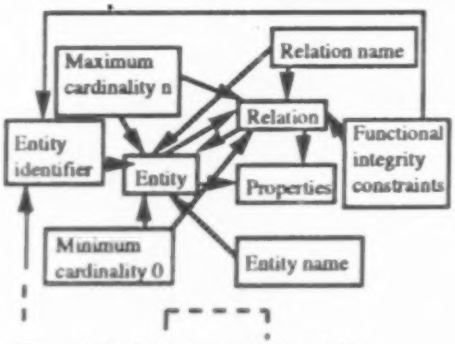

Figure 4. Links between prerequisites.

A network can be used in many ways. A learner can ask for the network showing prerequisites for a given concept. She or he can use it to have a given explanation by clicking on one box. Another learner can ask which box corresponds to a certain question she or he asked CODAMA. She or he can also see which box corresponds to a particular mistake that the advisor detected. Doing so, she or he will also see what are the related prerequisites.

The third underlined group of words, i.e., *List of Courses* (Figure 3), refers to a hypothesis that CODAMA makes. If the student clicks on those words, CODAMA will present a list that is supposed to exist within the organization. Note that, for some other cases, CODAMA will present hypothetical forms such as a bill. This allows the student to relate her or his perception of the reality to the entity-relationship formalism. That is what an analyst MUST do during all her or his professional life, i.e., verify repeatedly whether what he or she models is the real thing.

An advance organizer (Ausubel, 1960) can be used before starting the process of elaborating an ERD. First, CODAMA displays a complete and real ERD obtained from experts. A knowledge acquisition module allows the collecting of those real ERDs. It is described in the next section of this paper. The ERD being displayed, the organizer simulates the elaboration of this ERD. The simulation is made in accordance with a hierarchy of prerequisites

When the advance organizer module intervenes after a user begins to elaborate an ERD, it takes into account the learner's cognitive structure. There is a continuous collection of data that is invisible to the learner: questions asked and errors made are categorized and recorded.

Suppose that a learner used several menus but did not use keywords. CODAMA will fit its interventions. It could produce the advice presented at Figure 5. Following this advice, CODAMA begins a simulation of data modeling. First, it refers to the highest element of the hierarchy consulted by the learner. Then, CODAMA goes down the hierarchy to set the content of its next explanations. In other words, it presents the prerequisites. When the bottom of the hierarchy is reached, CODAMA goes back all the hierarchy. In the particular case illustrated at Figure 5, CODAMA's simulation puts more emphasis on explanations related to fundamental concepts and principles and less on the modeling technique.

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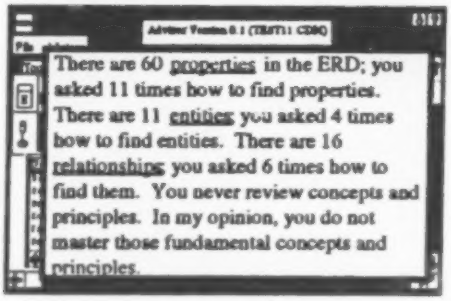
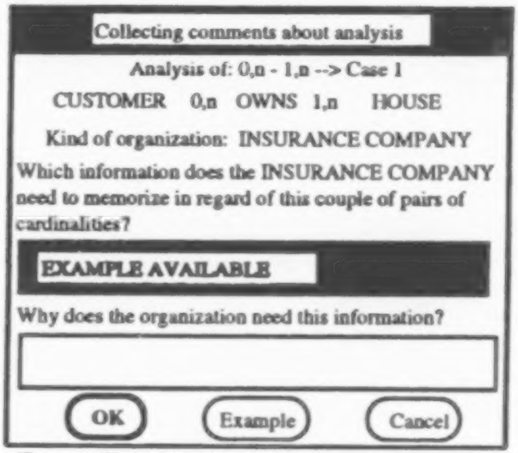


There are 60 properties in the ERD; you asked 11 times how to find properties. There are 11 entities you asked 4 times how to find entities. There are 16 relationships you asked 6 times how to find them. You never review concepts and principles. In my opinion, you do not master those fundamental concepts and principles.

Figure 5 Example of advice.

The knowledge acquisition module

The knowledge acquisition module allows the recording of real ERDs. To acquire those examples, experts firstly draw the ERD using the CASE tool (Figure 1). CODAMA's knowledge acquisition module is then made active. It begins by asking the expert to describe the organizational context. A specific part of the ERD is then explained. An example is presented at Figure 6.



Collecting comments about analysis

Analysis of: 0,n - 1,n --> Case 1

CUSTOMER 0,n OWNS 1,n HOUSE

Kind of organization: INSURANCE COMPANY

Which information does the INSURANCE COMPANY need to memorize in regard of this couple of pairs of cardinalities?

EXAMPLE AVAILABLE

Why does the organization need this information?

Figure 6 Example of expert's comments

In the following example, what an expert wrote to explain a minimum cardinality 1 is placed between <>: *Given a <manufacture of furniture>. Its clients are <retail shops, persons, and organizations>. This enterprise <makes to order>. When it receives an <order>, the following form is used* (Figure 7):

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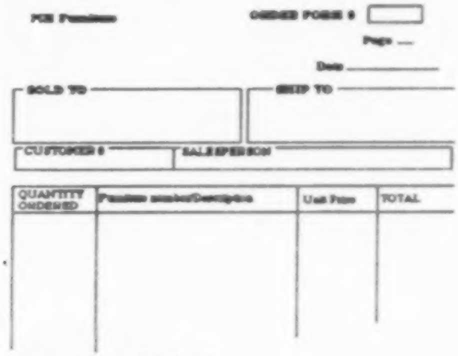

ORDER FORM #

Page —

Date ____________

SOLD TO

SHIP TO

CUSTOMER #

SALESPERSON

QUANTITY ORDERED	[illegible]	Unit Price	TOTAL

Figure 7. Order form

__Entities__ <Order> and <Furniture> and __relationship__ <Concerns> can be identified. An <Order> begins to exist in the memory of the organization when it <Concerns> at least one <Furniture>. That means a minimum cardinality of 1 is necessary.

Conclusion

Students, when asked what is an entity or a relationship, use less textbook like explanations and more examples. So, the advisor favors the transfer of knowledge. At the end of their curriculum, students have a training period within an organization. More than sixty percent asked to use CODAMA during this training period.

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Applying HCI Principles to Computer Based Higher Order Learning Environments

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Abstract: While computer-based learning has been going on for years in many different forms, more recent trends have been towards environments that promote higher level learning and that can effectively instruct in more complex subject domains. This paper explores the HCI issues particular to computer-based higher order learning environments and how these may be addressed via various implementations of HCI principles, as well as how general HCI principles can be applied in these applications.

Introduction

The content of a hypermedia/multimedia application may be right on target for an intended task but, if the interface between human and computer is not designed well, then the information and instruction may be ineffective or inaccessible. While screen design issues (i.e. placement of text, font sizes) are certainly a component of the human computer interface (HCI), this paper discusses HCI issues at a broader level, dealing with concepts such as the "intuitiveness" and "transparency" to improve the clarity, usability, and effectiveness of computer systems.

"Clarity, usability, and effectiveness" are far reaching, fuzzy goals. The domain, therefore, of HCI design is not clear cut or easily defined and ranges into a variety of issues including the physical arrangement and ergonomic configuration of computer systems, user operation of programs, and how the user interacts with the content to solve a task or to learn material. In the case of an instructional program, the relationship between HCI design and content also affects the instructional design of the program because the interface must not interfere with any instructional strategies embedded in the program. Therefore, some of the principles and guidelines discussed in this paper go beyond how users interact with the computer and program to include how the interface effects the users' interaction with the content in an instructional situation.

HCI Definition

Like many concepts, there are a variety of definitions for human computer interface design. In broad terms, Carroll (1987) describes the notion of human computer interface as "...computers as experienced and manipulated by human users" (p. xx). Reisner (1987) elaborates on this by describing the relationship as two-sided though uneven: we are able to predict specifically what the computer will do as the result of certain input; however, it is the unpredictable human reaction to the computer that we need to study and plan for in our design.

Palme (1983) presents an interesting metaphor which describes why HCI design is such an important consideration in program design. He contrasts the computer and the rules that create its interface to the rules that govern society. There are general rules that govern society behavior that are valid in numerous different circumstances. For example, loud noises, coughing, and talking are discouraged at movie theaters, concerts, plays, and church services. This is easy to understand and transfer to different situations for flexible human beings. The computer, however, requires a more complete and more rigid set of rules than society does, for a computer does not readily understand nuances or similarities in situations. The software must define every possible reaction for the computer. In society things are looser and there is more interpretation of the rules, meaning the rules are not always followed exactly the same way every time. This difference in flexibility and rigidness is one way of explaining why humans may have trouble dealing with a computer's set of inflexible rules, for while the human user perceives the differences inherent in different contexts, the computer only understands one reaction or algorithm. This is why the definition of the rules that make up the HCI are so important and complex.

For purposes of this paper, an HCI is defined as the layer of the software that communicates directly to and interacts with users. A sampling of critical components of a HCI includes:

- screen designs;
- all "messages" (error, status, etc.) to users;
- interactions, flow, or navigation between screens or other various parts of the program;
- inter-relationships between messages within the program.

Note that this list goes beyond the ergonomic factors such as the physical layout of the software and the ways humans access that software (i.e., keyboard, mouse, monitor) through the hardware configuration. An interface is interwoven throughout the entire program—it is in the way that the software reacts to users when they need help or make errors and in the way the content is presented. Likewise, the principles and design guidelines that follow must deal with these diverse aspects of a HCI.

BASIC HCI PRINCIPLES

Guideline 1. Conduct an audience analysis to guide the development of the human computer interface.

A central HCI design principle is to analyze the characteristics and needs of the audience (Carroll & Rosson, 1987; Bailey, 1985). Although instructional programs include an audience analysis as part of any instructional design, audience analysis for the HCI differs slightly from audience analysis in instructional design (ID). ID learner analysis focuses on the cognitive, affective, and prior learning characteristics of the learners. ID analysis looks for characteristics that will facilitate or inhibit learning. Task and performance analyses for HCI emphasize analyses of intended usage patterns and technological attitudes and abilities. The following guidelines look at how to address these HCI issues.

Guideline 1a. Examine the problem the user intends to solve with the software.

While this guideline does relate to ID's task analysis, one must go a bit further in this analysis for HCI design. ID always examines the principle subtasks inherent in completing the main task. One factor to consider in the HCI analysis is whether any of the subtasks can be performed by the interface rather than the user to help the user maintain appropriate cognitive involvement.

For example, if the task is one that users are familiar (e.g. writing a check, solving a common mathematical problem, or entering data in a frequently used program) with then the HCI can take advantage of commonly known terms and perform mundane steps to enable the users or learners to focus on new steps and new learning. That is, users may know how to write a check without a computer; therefore, in a new computerized version, the HCI would guide the user through the well known steps using common terminology and emphasizing unfamiliar tasks of the computer version. On the other hand, the opposite situation may be true. Students may be so engaged in a new, large task (e.g., simulating a science experiment, comparing geographic information) that they fail to see and adequately perform the subtasks. The interface must ensure proper attention to detail and cognitive subtasks necessary to complete the larger task.

Another aspect a thorough user analysis is to look at users' prior behavior patterns in performing the task. Sometimes a new program is built to replace an old program. In that case the following questions are asked.

- Did users perform the task on a computer before? If so, will the new solution be a similar type of program or very different (i.e. going from a DOS environment to a Macintosh)?
- What did users like and dislike about the prior program? Were disliked factors a result of poor implementation?
- Were users forced to use it against their will thus creating a bad attitude that no matter how good the program it would not be appreciated)?

If software was not used before, these questions won't apply. The following questions should be examined for this class of users, but are also useful when the audience has used computers before for the task.

- What are the users attitudes toward using computers? For instance, have they had or heard of experiences where computers have "replaced" people, or had any other experience that may cause them to have a negative predisposition to any software introduced.
- Should the program imitate the existing way of accomplishing the task exactly? The wider the difference between the computer method and noncomputer method, the flatter and longer the learning curve.

Once designers have collected this information, it can be used to make decisions about not only the HCI, but also what else might have to be done in order to achieve success with the product. For instance, if there is a negative attitude regarding computers, the software may have to be accompanied with assurances from some trusted body or individual that this software is not threatening any person's job, or that a learner's prior

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bad experience with a "drill and practice" program does not necessarily mean they won't succeed with the current environment.

Guideline 1b. Examine the users experience level with computers and other relative kinds of software packages.

The users' experience with other software packages tells something about what expectations and what metaphor they may bring to the product being designed. If users have experience with command line systems and programs (e.g., a DOS or UNIX system where users must know the command to enter to achieve the desired action, versus a menu driven system), then a system or program that relies on icons and menus, while supposedly easier to use, may be unfamiliar and difficult to those users. This means that a significant amount of education will need to be done before users will adapt the new system and more on-line help may be required.

An interface can also attempt to relate the current interface's functionality back to a system users are already familiar with. So a help message about pull down menus might define them in terms of a command-driven system. An extension of this concept is to actually create an interface that allows multiple modes for running the system; that is, there might be an option to emulate a command-line system (or whatever system type users are familiar with) rather than using the pull-down menus. If the user community's prior experience is not homogeneous, as is likely to be the case, designers may not be able to accommodate all styles within an interface (just as instructors are not able to adapt to all individual learner characteristics), but may need to model the interface metaphor as described before, so users may have a better chance of knowing what to expect of the interface.

Guideline 1c. Examine user attitudes toward using a computer for the intended task.

Users bring many attitudes toward computers. Some may see if as a great "tool" that can make them more powerful on their job, while others may feel quite threatened. The latter group may have heard or experienced folks losing their jobs as use of computers increased. Knowing this type of information can affect the final product in a couple of ways. First, while designers should always strive for the best, in a case like this, being extremely sensitive to a friendly, easy-to-use interface that clearly shows the benefits to users becomes even more important. Even sensitive interface design, though, may not totally compensate for these pre-existing attitudes, so a design team may want to suggest that the product introduction be accompanied with written or verbal materials that attempt to ease users' concerns.

On the other hand, if users bring a positive attitude toward the system, then they ought to be able to find the kind of functionality they expect in the product. The interface should make this functionality obvious and simple so it can capitalize on users' enthusiasm. The rub for designers comes when trying to adapt a system to work well for both users looking for lots of functionality and those that are more timid with the product. Some suggestions for scaffolding "progressive turnover" of functionality to users as their expertise increases are discussed later.

Section Summary

To summarize how HCI's audience analysis principle should be factored into instructional design:

- Task and front end analyses should be expanded beyond learner characteristics to include user attitudes and task accomplishment patterns.
- All stages of design and implementation should balance and measure themselves against the needs of users in terms of program operation and program purposes.
- When in doubt or when other principles or heuristics are in conflict always turn back to users' needs and characteristics and make decisions based on them.

PRODUCTION BIAS

Guideline 2. Design an interface that encourages exploration and makes learning efficiency a rewarding experience.

Production bias (Carroll & Rosson, 1987) means that users are interested in completing their target tasks, or in other words they are "biased" in their use of an interface toward getting their jobs done. They are intent on being productive. This isn't a bad tendency if the path they take to accomplish their task is the most efficiently designed path. However, using the computer efficiently or as the program designers intended is often of little consequence to users. Their production bias motivates them to finish the task any way they can—efficient or not. This bias discourages users from taking time to do any system exploration, experimentation, or documentation reading, because anything not directly associated with getting the job done seems a deviation from their goal and a waste of time. Users may desire a more efficient way to perform a task and may even suspect that such a method exists, but the desire for task completion will outweigh the desire to find a more efficient alternative.

While knowing users' degree of production bias isn't totally possible, there are a few things to consider that may be helpful in both estimating the bias and determining how to deal with it. Once again these come back to the importance of a thorough audience analysis. A design team may try to determine the users' prior "patterns of use" with previous pieces of software; particularly patterns associated with learning new functionality or willingness to conduct system exploration. In many programs it may be possible to collect evidence in frequency of use of *help* facilities or training and documentation.

If users don't use these help facilities, then find out why. Is it that they have tried and they have been frustrated by not finding what they need, or is it that they just haven't tried? In either case, the implication for the HCI may be to couple the interface with other aspects of the product that encourage exploration and new learning. For instance, a button labeled "Catalog" may result in a pop-up window that says

"Enter the name of the new catalog:____.
For more information about what catalogs are and how they are used, press the help button below."

Production bias also effects the instructional design of the program. For example, students may want to finish the program as quickly as possible to get back to "real" work activities (or recess). Extrinsically motivated students tend to do the minimum to finish an assignment (Keller, 1983). Their level of learning is not the goal, but simply assignment completion. The strategies the learner uses to learn the material are a matter of student choice, but can be effected by careful instructional design. However, careful HCI design can help make sure that the strategies are implemented. Handling the production bias may be a simple matter of limiting user options. If it is important for users to read and study a particular sequence, the interface and strategy can require a thoughtful response before continuing and prevent users from "escaping" to another part of the program before the section is complete or before the objective is achieved. Similar to interface design, the instructional design of the program tries to develop strategies for the instructional interface to motivate learners to go beyond the minimal target goal. If high level learning is a goal of the program then the program interface should support this via exploration encouraging methods such as inquiry teaching (Collins & Stevens, 1983).

A second instructional design factor affected by production bias is the opposite of the previous example. Instead of lightly covering material, students try to memorize everything they encounter for they believe that is their task. For example, programs that inplement cognitive flexibility theory, such as KANE (Spiro & Jehng, 1990) require the learner to dynamicaly link back and forth between a number of nodes examining many perspectives on the complex topic (KANE explores the motivations of the character Kane in the movie *Citizen Kane*). The learners may be so unaccustomed to this mode of learning that they assume their task is to learn (read or memorize) everything encountered in the system and not use the interconnections between nodes to construct their own views as the program intended. So, their production bias leads them to accomplish the wrong task.

Guideline 2a. Given that production bias leads users away from system exploration and learning, make efficient task completion obvious within the user interface.

Realizing that users may perform shortcuts or, conversely, accomplish a simple task with an unnecessarily complex routine, HCI designers need tostrive to make efficient task accomplishment obvious within the user interface. In other words, the interface should lead users to the most efficient ways to accomplish a task. In *Desert Shield* , for example, information access is the prime purpose. Therefore, the interface design focuses on letting users access information in multipleways: from the menu bar, a main table of contents, and within fields on the screens. The designer's goal was to provide direct access (one mouse click) whenever possible.

Another way of accomplishing this is to utilize a functional organization of on–line help rather than (or in addition to) a topical organization. For example, users may need help on step five of a process, so the interface shouldn't force them to look at one through four. *Desert Shield* uses a functional system of on–line help by letting users access a help topic for a menu or button choice directly by holding the option key down when clicking. Again, this gives direct help without taking the user through a long set of hierarchical screens.

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Guideline 2b. Describe task functions, buttons, and menu options using words, phrases, and icons that are familiar and have meaning to the target audience.

A great deal of good interface design is in the language used for describing objects and tasks. For example, a table of contents or index entry should read *Moving Text* rather than *Steps in Cut and Paste*. "Moving text" is the task users try to accomplish; "cut and paste" are names for the operations defined by the system developers. The names may be descriptive, but they are not as descriptive as what may be familiar to users.

The notion of simple and direct naming should also apply to the design of icons. Graphics-based interfaces like Windows and Macintosh foster the development of icons instead of words to label buttons and functions. Although a lot of thought goes into these icons, they are often a mystery to common users. All words, phrases, and icons need to be tested in a formative evaluation process.

Section Summary

The production bias says users are interested in task completion. Their interest in completion is so strong they may not take the time to discover the most efficient way to accomplish their task. While there is probably no way to eliminate this bias, instruction or a HCI can try a couple of strategies. Functionality that you want users to take advantage of needs to be clearly and easily available. Users shouldn't have to look far. Additionally, designers should try to find out how much the production bias is in effect by looking at how users have learned new concepts and methods in the past.

ASSIMILATION BIAS

Guideline 3. Correct any misconceptions or inappropriate knowledge brought to a new way of accomplishing a task from prior experience and learning.

Assimilation bias (Carroll & Rosson, 1987) states that users' previous knowledge base may obscure new learning. It is similar to the production bias described above in that users end up sticking with the way that they are familiar with to get the job done rather than exploring or looking for more efficient methods. In assimilation bias, users are led to an inefficient way of task completion because of preconceptions from prior learning. Users are comfortable with their previous way of accomplishing a task and resist a change to another method. They are reluctant to assimilate the new methodology into their working or study habits.

Assimilation bias is evident in HCI design when the computer program operation may be so new and different that users seek a familiar sequence and methodology to accomplish their task. User-familiar items can be defined by prior knowledge of and experience with other systems or can be learned from a co-worker who, even though a novice also, may be perceived an expert in comparison. In this way, system misinformation and incomplete information spreads among users. From this incomplete information, users may also formulate theories and rules about the rest of the system which may be incorrect.

Guideline 3a. Write informative error messages to tell a user *why* something went wrong, not just *that* something went wrong.

Inappropriate prior knowledge and its consequences must be discovered and remedied. Much of this must be dealt with in the original planning and formative evaluation of the interface, for the HCI tends to remain static once implemented. In an interface, a misconception generally takes the form of an incorrect system view. In most systems, the only opportunity there is to correct such views is when an error occurs. Therefore interface designers must not only consider designing clear error messages, but also suggest ways to correct not only the error at hand, but the underlying misconception as well.

Guideline 3b. Design the interface so users can't "hurt" anything, or have the perception that they have hurt something.

This guideline can mitigate the effects of the assimilation bias. If users believe that they "hurt" something, they may become shy with the system and become reluctant to try new things, thus exacerbating both production and assimilation biases. This guideline is probably more critical as applied to the novice user who approaches the computer with some trepidation. A significant factor in implementing this guideline is a thorough system evaluation

A second way to help encourage users to learn different routines is to build in an *undo* and *go back* functions. Unfortunately, these commands may be difficult and expensive to implement as they require the system to save snapshots before and after every given command. Less expensive attempts at user safety include warning messages when the user is about to do something with sweeping consequences, such as removing the contents of an entire directory/folder or not saving the results of a two hour CAI session.

Section Summary

The assimilation bias states that user's prior knowledge may obscure new learning. The functional ramifications are similar to the production bias in that users may not use the interface's full functionality but rather stick to tasks they know. Designers can use the following strategies to counter-balance the effects of the assimilation bias.

- user error messages to correct/modify incorrect system views,
- correct errors as soon as possible so incorrect system models are not cognitively strengthened inadvertently,
- make the interface impervious to harm so if learners do explore, they will not have the perception they have damaged anything; this friendly exploratory environment may lead to further exploration and discover of new interface functionality.

INTUITIVENESS

Guideline 4. Design an interface that is intuitive, logical, transparent, and direct to users.

To be intuitive in the context of HCI design, the interface must adapt to the reality of how users think versus expecting users to adjust their thinking schemata and strategies to an arbitrarily designed interface. If an interface is intuitive, the interface falls easily within the expectations and experience of the users, therefore the users will not have to make much of a leap to place their cognitive processes about the problem they seek to solve within the confines of the system. The normal way they approach the target task should be readily represented within the system's interface.

Concepts related to intuitiveness include transparency and directness. Designing a *transparent* system means that program operation doesn't interfere with users performing program tasks. Transparency in an interface helps create a system that is easy and non-intimidating to use. A transparent interface takes little cognitive overhead and puts few, if any, demands on users. Icons, pictorial representations of interface functionality, are a potential example of interface transparency. A small picture of a computer printer on a button is thought to be transparent for most users because it is an easy leap to understand the function the button activates.

An interface that is *direct* helps users believe that they are engaged in accomplishing their goal. An indirect system serves as an obstacle to accomplishing goals (Hutchins, Hollan, & Norman 1985). For example, a word processor that is direct helps users believe they are writing a story and not using a word processor to write a story. A CAI program that is direct helps students believe that they are learning valuable information rather than operating a computer program about information.

Welsh, Murphy, Duffy & Goodrum(1993) found that a non–intuitive, non–direct way of labeling hypertext links had negative effects on how much students accessed the information via that link. Once students chose to access the link, they received a sub–menu of choices from which they had to choose again. The effect of this indirection was students simply avoided accessing the links at all. The same experiment showed direct link accessing methods where information was presented as soon as the link was chosen were used more frequently.

Another way of describing the principle of intuitiveness is via metaphor matching. Users come to an interface with a metaphor about how the program functions. A metaphor creates a set of expectations among users about how difficult a task will be and how they will perform that task. For example, when Apple Computer introduced the Macintosh, they also introduced a new metaphor for computer operation, the desktop. Users are encouraged to view the computer as a desktop with a series of folders to organize their work. If the interface operates consistently with the users' metaphor, then the interface feels intuitive or natural. If not, users must adjust their metaphor or expectation in order to use the system most effectively. Then the interface is not intuitive, transparent, or direct.

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For example, frequent users of command line driven systems (a "command line driven" system takes most of its user input via commands that the computer understands typed in via a keyboard) , like UNIX® and DOS®, may expect computer interactions to consist of typing a command at a prompt and then getting a response. When command line users are first exposed to a system using the desktop metaphor (e.g., Windows or Macintosh), they find that their expectations are not met. Users have to adjust their expectations in order to use the desktop system without having to translate the commands they would have normally typed into the equivalent desktop inputs. So what was intended to be a very easy interface to adapt to, turns out, at least a subset of users, to be quite a leap.

As effective as a metaphor is in tapping into something familiar and easy to grasp for the users, it can be overused and actually decrease transparency. Jonassen (1989) cites an example of using multiple windows in an interface. Placing programs and files in windows on the screen can be an intuitive interface device because they extend the concept of the single view of an application or task to multiple views. This may be intuitive to a point, but when too many windows are available on the screen they have the opposite effect. Users can only juggle effectively a few windows at once, just as a person can only keep a few items in short-term memory. So, once the number of windows gets beyond a threshold, depending on each user and the context in which they are using the interface, they become a hindrance as the user to has to concentrate on the windows rather than the tasks they contain.

The interface should also help make the instruction intuitive. Instructional design theories such as cognitive apprenticeship (Collins, 1991) also have goals of intuitiveness and directness. These instructional methods strive to immerse learners in a real-world learning experience to make the learning effort intuitive while focusing on a realistic task.

Guideline 4a. Keep the interface simple and basic with a limited number of options.

Avoid designing an interface that is too feature-rich, or too busy. There is a basic set of functionality users need in a software package in order for it to provide an enhanced way of accomplishing the desired task. While it is true that multiple ways to achieve a task may help an interface work for novices and experts, too many options may confuse users (especially the novice) and actually detract from the interface's usability. From a cognitive processing point of view, users must chunk away all the options in short term memory, and if there are too many of them, their own processing is bogged down causing confusion and reduced interface transparency (Andre & Phye, 1986).

For example, the development of software for phone switches (which these days are complex computers), results in the conclusion that most users don't want or need the feature richness provided in these systems. The multitude of ways to answer calls and place them on hold, and many of the features provided for accomplishing those functions often go unnoticed and unused. Users evidently find one way or possibly two ways that are intuitive to them to accomplish the task, such as answering the call, and don't search any further for others unless their needs change and that need outweighs the effort of looking for and learning a new feature. So users, in this case, actually provide their own simplicity in an interface that offers too many options.

Guideline 4b. Balance the locus of control between the interface and users.

Designers should build an interface that encourages users to interact with the system in substantive ways that reflect the actual nature of the task. For example, some of the older, line-oriented word processing programs had such severe limitations on how to represent information that users had to format text in their minds rather than on the screen to meet the text editor's demands. The antithesis of these editors are today's WYSIWYG (what you see is what you get) editors where users have almost total control over the final appearance of the text. Although, in the first case, users may eventually memorize all of the editor's interface rules, these rules are not substantive parts of the actual task. In the second case, the interface design has adapted to the users to give them more control over the job. This frees users to concentrate more on the content of their text instead of concentrating on how to use the tool.

Section Summary

Ironically, there is no intuitive way for a designer to necessarily create an intuitive or transparent interface. However, designers need to consider their audience and design interface attributes that fit as easily as possible in to the users' cognitive structures. Keeping the interface relatively simple and balancing control between the interface and users are ways designers may promote interface intuitiveness.

Intuitiveness, directness, and transparency are important elements of a successful interface. In order to design these characteristics into the interface, designers must understand the characteristics of the intended users and the intended use of the system. This level of understanding includes the expectations and metaphors users bring to the program, as well as how to best actively engage the learner in the completion of the tasks they are working on. In sum then, the interface must allow users to concentrate on their target task instead of the interface itself. If an interface can accomplish this, it has achieved an important level of intuitiveness, directness, and transparency.

CONCLUSION

This paper has discussed the principles and guidelines for HCI design with emphasis on these principles for hypermedia and multimedia design. Principles discussed included

- doing a thorough audience analysis to determine both users abilities and prior experience with computers and interfaces as well as attitudes,
- accommodating the users production bias by encouraging exploration within the interface,
- accommodating users natural assimilation bias with an interface that corrects inappropriate prior knowledge that may limit users abilities within the interface,
- designing an interface to be intuitive, logical and clear to users,
- and building an interface that supports adapting and growing with the users rather than the other way around.

There is no doubt that these concepts are difficult to grasp and even more difficult to implement as a designer. However the importance of a well-designed HCI can not be over stated. The HCI is the primary way users interact with a learning environment and if they find it difficult to use, their learning may be compromised. Conversely, any design effort that results in an HCI that allows users to focus on the learning task at hand and enhance their abilities in that arena, while it may not be overtly acknowledged by users, will pay off with users having a more satisfactory experience with the learning environment.

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User-Interface Attributes Supporting Metacognition in Computer-based Learning Environments

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Introduction

The field of computer-based instruction (CBI) has grown by staggering leaps and bounds in the past ten years. Additionally how programs are controlled and what they look like has changed. Early CBI programs were typically tutorials which were linear in nature and offered few choices beyond "Press the Space Bar to Continue." Today's programs are a fusion of buttons, pull down menus, cascading windows, and overlapping control panels. While these technological advancements make programs more powerful and impressive, the technological breakthroughs of today and tomorrow must be harnessed in order to make these complex new programs effective tools that can promote human learning.

The purpose of this paper is to examine how metacognitive theory can be integrated into the design of the computer based learning environments through the user interface. A description of interface design and metacognitive theory will be presented, and, a list of organizing questions will be used to demonstrate how metacognition can be integrated into the design of a user interface.

Interface design

The interface of a computer-based instruction (CBI) program can be likened to a control panel from which users access information in an oftentimes sophisticated and complicated piece of software. Users must be able to control course presentation, access the elaboration of unknown terms, initiate animations, manipulate objects such as multiple windows, navigate to test items, make responses to questions, be able to ascertain where they are in the program, and know how well they are progressing. All of these activities associated with CBI contribute to the interaction style of the program. The interaction style of a program depends on the number and kind of tasks learners are required to perform in a program, and the number of choices available to them. Once an interaction style has been determined, the designer can then begin determining how the choices required by the users can be physically laid out. Interaction styles can be manifested within the interface as physical representations of choice. Interface design elements as menus, buttons, multiple windows, help and navigational aids, and response types (Jones, 1993) represent these choices. The design of the user interface serves as a cognitive dashboard from which users can control the program and monitor their progress towards the end of learning the information contained in the program. In short, the interface of the program often represents the implementation of the instructional strategy of the program.

Metacognition

Ideas and theories stemming from the current popularity of cognitive psychology continue to influence the theories of instructional design and the development of computer-based learning environments. Research on the use of complex skills has led cognitive scientists to include cognitive strategies as a type of skill that is used to

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solve difficult problems. This special type of intellectual skill is an "internal process by which learners select and modify their ways of attending, learning, remembering, and thinking" (Gagne, Briggs, & Wager; 1988).

Cognitive strategies include rehearsal strategies, elaboration strategies, organization strategies, affective strategies, and comprehension monitoring strategies. These strategies are cognitive events that describe the way in which one is processing information. The design of a computer-based learning environment should take into consideration the users ability to engage in, preference for, and appropriateness of various cognitive strategies.

Metacognition is a type of cognitive strategy that is said to have executive control over other cognitive strategies. In the context of learning through a computer-based learning environment, metacognition refers to the cognitive activities of a user to monitor, regulate, and orchestrate learning processes (Flavell, 1979). Figure 1 describes components of metacognition.

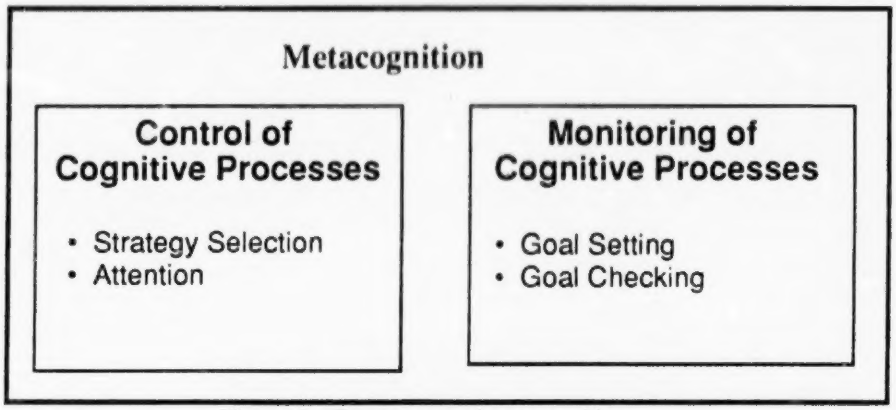

Figure 1. Components of metacognition

Four individual strategies within metacognition include strategy selection, attention, goal setting, and goal checking. These strategies can be grouped into two major categories: 1) control processes and 2) monitoring processes. The two categories of metacognitive processes are described below.

Control Processes

As the executive controller of cognitive processes, metacognition selects the appropriate strategy for the task at hand. The selection of a cognitive strategy depends upon the individual's understanding of the current problem or cognitive situation. Personal experiences in solving similar tasks and using various strategies will affect the selection of a cognitive strategy. For a learner, this may involve the selection of rote rehearsal as a strategy for learning particular facts such as a list of vocabulary words.

An individual can also choose to attend to particular cognitive strategies. This strategy, attention, is important in following-through, completing and correctly performing the steps of subordinate cognitive strategies. In other words, this metacognitive strategy maintains one's interest in using a particular strategy after that strategy has been selected.

Monitoring Processes

Cognitive processes such as learning and problem-solving often begin with the identification of a goal. In learning, this might be an understanding of a particular topic; in problem-solving, the goal would be to find a solution (or the best solution) to the problem. Goal setting guides the cognitive strategies in a certain direction. Goal checking are those monitoring processes that check to see if the goal has been accomplished, or if the selected strategy is working as expected. This monitoring process is active throughout an activity, constantly evaluating the success of other processes. If a cognitive strategy appears not to be working, an alternative may then be selected. Various prescriptions for instructional development proposed by Redding (1990) are primarily concerned with giving metacognitive guidance in problem-solving situations. This guidance includes many familiar methods such as advance organizers, graphic representations of problems, and hierarchical knowledge structures. These instructional methods should be used to aid the novice in developing an expert's awareness of

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problem space. "The most effective way to turn a 'poor' novice problem solver into a 'good' novice problem solver, and thereby facilitate development of expertise, is to teach the student problem space representational skills" (Redding, 1990).

Metacognition is the "management" of thought processes as one learns and solves problems. In the context of a computer-based learning environment, learners are presented with large amounts of information, and asked to sift and sort through that information to solve a particular problem, or learn about a particular topic. In order to assist the management of this information, the interface should provide users with relevant information about the program, how to use the program, and how well they are doing in the program. To effectively use these programs, users will need information, and users will have questions. We have chosen three organizing questions that users will have when confronted with a computer-based learning environment, and provide suggestions for how a designer might provide users with relevant information: What is it? How do I use it? and What do I know? In a previous study, Jones (1993) sets forth a list of concepts of user interface design and corresponding guidelines for implementing those concepts. Using the organizing questions presented in this paper, we will attempt to provide guidelines for designing user interfaces which can answer these questions for users.

What is it?

Learners select and use programs based upon unfulfilled needs or particular interests. If the program is selected as a learning activity, then a goal has been established. The use of a program often results from a decision to reach a goal through a particular strategy. Goal-setting and strategy-selection are key elements in the personal management of cognitive processes. Users ask themselves: "Does this program fulfill my need, and will I be able to use the program efficiently and effectively?" To assist the learner with this management, it is the responsibility of the program to communicate the content and scope of the environment. In the event that a prospective learner has an ill-defined goal, it is the responsibility of the program to provide suggestions.

"What is it," our first organizing question, refers to the initial way that the program refers to what the program is all about. Users will need information about the subject of the program, the scope of the information contained in the program, and the type of information contained in the program. This information is needed not only when users start the program, but throughout the program as well. In a complex computer-based learning environment, users may have questions about the scope of the program throughout the entire program. Three concepts of interface design (Jones, 1993) address the question of What is it? as it applies to the providing metacognitive support within the user interface: Metaphors, Browsing and Closure.

One way that designers can answer the question of "What is it?" for users is through the use of a program metaphor or organizing theme. Metaphors help users define what information is contained in a program by relating it to a known function or process taken from an area or discipline familiar to the users (Jones, 1989). Program metaphors such as books, book shelves, space exploration, or buildings with different rooms help users to organize the program's content and the access to the content contained in the program. The following guidelines can help designers provide users with efficient program metaphors.

1. *Use a metaphor or theme for the program.*
   Not every program needs a metaphor. Not all programs can support a metaphor. Study the content carefully and decide what the program is intended to do. Providing users with a theme can be more helpful than a forced or inappropriate metaphor.

2. *Make the metaphor obvious to users.*
   Try prototyping the metaphor and its controls and testing it with potential users. Be careful of trusting your instincts on whether of not the metaphor is obvious, and get the opinions of people who are not familiar with the program.

3. *Make the metaphor applicable to the program's content.*
   If a metaphor can be used, use a metaphor that reflects the program's content. Users should not have to learn the meaning of a metaphor and the content of the program. Some metaphors may be intended to reflect the theme of a program and not necessarily the program's content. For example, a flight simulator would probably use the metaphor of a cockpit to show users how a plane works. However a program on different airline regulations might use a metaphor of a resource manual or book.

One way that users often acquaint themselves with the information contained in the program is through the process of browsing for information. Browsing allows for the flexible exploration of the content of the program through a variety of controls (Jones, 1989; Laurel, Oren, & Don, 1992). Browsing can be done topically by providing users with a list of the topics covered in the program through the use of a menu. Once a topic is selected, users can use methods such as clicking on right and left arrows to access related or extended material. While browsing should be flexible and exploratory, it should not be indiscriminate or uncontrolled. Users need to be able explore the program for new information, know where they found it, and be able to find it again. The following list of guidelines can help designers provide for effective and innovative methods of browsing in their programs.

1. *Provide selectable areas to allow users to access information.*
   Some possible selectable areas to consider are buttons and hot text within a text field. The location of these elements on the screen will depend on the available screen real estate and the function of the selectable areas. It is recommended that the placement of selectable areas be tested with users to find out what is the optimal location for them. The selectable area will be a control element for users to access information. The control chosen will depend on the task to be done. Be consistent in implementing particular controls for particular functions.

2. *Allow users to access information in a user-determined order.*
   This may be done through topic indexes of all of the information available in the program, or through the use of different types of menus. Another technique to consider is allowing for user-entered search terms. Exploration should be flexible, and the controls for accessing information should reflect flexibility.

3. *Provide maps so that users can find where they are and allow provisions to jump to other information of interest from the map.*
   Because the content of computer-based learning environments tends to be complex, using visual or iconographic maps may be too difficult to include and too confusing for users to understand. What we now consider as maps may have to change drastically. Text based indexes, outlines, and tables of content may be considered as alternatives to maps.

Another method that designers can use to help users answer the question of "What is it" is by incorporating closure (Jones, 1989) into the program. Providing users with closure can help organize the information in the program into manageable segments so that users are not overwhelmed by the amount of information contained in the program. Organizing information requires that methods be used to allow users the ability to access information in a controllable fashion. The following guidelines can help designers provide closure within a computer-based learning environment.

1. *Provide users with information that lets them know that they are making progress.*
   Because the information in computer-based learning environments is not organized sequentially, there is no determined order that users must follow through a program. Consequently users may feel that they are working in a program without making progress. Some techniques that may be considered to give users a sense of accomplishment are path history mechanisms that tell users what information they have seen, or visual cues that indicate progression. Another technique would be to break the program up into chunks that may give learners a feeling of accomplishment.

2. *Arrange information in a non-threatening manner so that users are not overwhelmed by the amount of information contained in a program.*
   To accomplish this consider setting up information with an overview of a topic that acts as a top layer of information. As users need more information they can move progressively deeper through the layers of information. Moving through the layers of information could be done through the use of pop-up menus, buttons, or hot text.

3. *Provide visual effects to give users visual feedback that their choices have been made and registered by the program.*
   Buttons, icons, and menus can be highlighted or animated to show users that a choice has been made. Keep the highlighting or animation simple. The duration of a highlight or animation should be long enough to be registered visually by the users, but short enough so that users are not waiting for an animation to be over so that they can get to the information they want.

Jones, M.G., Farquhar, J.D. & Surry, D.W. (1994). User-interface attributes supporting metacognition in computer-based learning environments. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 186-192). Nashville, Tennessee: Omni Press.

Visual effects, such as wipes, fades, and zooms may be used to indicate access to a particular piece of information. The use of these visual effects should be consistent. Do not use them simply because they are available, but rather use them to indicate a particular action of the program. Additionally, be consistent in the use of a visual effect. If wipes are used when clicking on a right arrow, use them throughout the program. If zoom outs are used when clicking on a menu item, then use zoom ins when returning to the menu. Above all, make the visual effect have meaning and be consistent with its use throughout the program.

How do I use it?

Managing cognitive processes involves the constant selection of learning strategies. Once a goal has been set, learners will ask: "How do I achieve my goal?" One of the benefits of large multimedia environments is the availability of numerous learning strategies. Some programs offer a seemingly endless variety of accessibility and interactivity options. Other programs present a select few. In assisting the learner with the process of strategy-selection it is imperative for the program to communicate options and recommend methods.

Invariably, when faced with a complex computer based learning environment, users will need to know how to use the program. For designers of computer based learning environments, it appears fairly clear: read the screen, highlight information, click on buttons, and pull down menus to go where you want to go. However to novice users, these are not natural activities. Consequently, designers need to make the functions of the program not only easy to use, but easy to learn. Answering the question "How do I use it?" is imperative for novice users. Three concepts of interface design (Jones, 1993) address this issue as it applies to providing metacognitive support in computer-based learning environments: Information access, Interactive Tools for Interactive Tasks, and Unfamiliar Territory.

Implementation of the concept of information access (Laurel, Oren, & Don, 1992) provides users with the controls to conduct deliberate searches for information to fill a particular need. These information needs could be to search for an answer to a specific question, or to find and organize information for a report or presentation. Information access is sometimes manifested through user entered search terms, or by providing users with an accessible index to all of the information contained in the program. Some guidelines for providing for information access follow.

1. *Allow for guided searches for specific information.*

   This may be done through the use of indexed lists of all the information contained in the program, or by letting users type in search terms. Additionally, designers may consider using some type of path for users to take through the program when searching for certain types of information. For example, if a program is on baseball, designers may provide predetermined paths such as "the evolution of the designated hitter rule," or "Joe Pepitone's career from 1965 to 1970."

2. *Allow users to search for information across different media types.*

   This guideline may be one that is not employable at the moment. It accounts for idea or concept searching for information within different media types. While interactive video allows for access of designer determined sections, all video needs to be searchable for single words, phrases or ideas. Video needs to be cross referenced with other types of information in a user determined manner.

   Searching for video and audio by key words is technically difficult. This type of searching may be accomplished through the use of verbatim transcripts of audio and video segments that are arranged by different ideas and concepts. These ideas and concepts could then be active, as hot text or hypertext links, allowing users to select them to go to the accompanying media.

The concept of interactive tools for interactive tasks (Reingold, 1990) suggests that tools for interacting with the information contained in the program need to be appropriate to the task, and capable of supporting the program theme. The form of the control needs to reflect its function, and the function of the control needs to be consistent with the program theme. For example, if the program is intended to simulate the control of an airplane, then the buttons and other manipulatable areas on the screen need to look like controls found in an airplane. Designers are encouraged to "push the envelope" of what authoring tools can do in order to develop better and more efficient interactive tools. Even if you don't know what to call it, you can still develop it. The following guideline can help one push the envelope.

1. *Provide navigational tools and interaction styles that allow users to interact with the information contained in the program in a manner that is consistent with the metaphor.*

Jones, M.G., Farquhar, J.D. & Surry, D.W. (1994). User-interface attributes supporting metacognition in computer-based learning environments. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 186-192). Nashville, Tennessee: Omni Press.

If the metaphor of your program is that of a book, then tools such as a table of contents, pages, and chapters could be used. Select tools that are consistent with the metaphor. Design icons that reflect the theme or metaphor of the program. As in the building of a Frank Lloyd Wright home, the form of a control should reflect its function. Additionally, the controls should be integrated harmoniously into the metaphor of the program.

One of the problems that users face when using a computer-based learning environment is in navigating through the unfamiliar territory (Nicol, 1990) that is the problem space. Manifestations of the concept of unfamiliar territory provide users with visual or verbal cues that help them begin to learn their way around a new learning environment. Overviews, menus, icons, or other interface design elements within the program should serve as advance organizers for information contained in the program. Users new to a program need to have methods built into the program to serve as organizers for the information in the program. The following guidelines may help designers build effective organizers into a program.

1. *Provide cues such as maps and menus as advance organizers that help users conceptualize the organization of the information in the program.*
   Advance organizers can help users know what information is available in the program so that they have some direction about where they need to go in the program.

2. *Use a fixed format of frames to keep the information at the same place on screens.*
   If more than one format for screens is needed, keep the format constant for individual sections.

3. *Provide users with program orientation.*
   Video overviews, overviews in the program documentation, and overviews in the program can help orient users to the amount and type of information in the program.

4. *Provide users with information to let them know where they are in the program.*
   Section titles, standard borders for specific types of information, constant backgrounds for a particular section, and even icons help users can let users know where they are and what they can expect. Additionally, using different shapes can let users know where they are in the program.

5. *Use location indicators and progress reports to let users know where they are, where they need to go, and how long it will take them to get there.*
   Location indicators and progress reports let users know where they are and where they need to go. These location indicators may be likened to the signposts or mile markers one would see while driving on a highway that tell you what road you are on and how far it is to the next town. These are particularly useful when users are trying to solve a problem or answer a question provided for by the program. Location indicators and progress reports may be represented through text messages, graphics, or pop-up windows.

What do I know?

As we have indicated throughout this paper, metacognition, or the management of cognitive processes, involves goal-setting, strategy-selection, attention, and goal-checking. The question of "What do I know?" addresses the issue of goal-checking. Here, the learner will evaluate the effectiveness of the selected strategies. The learner will ask: "Have I learned something? Have I achieved my goal? Were the strategies I chose successful?" The user interface of a program can support this knowledge in a variety of ways.

We do not present a formal list of guidelines for the question of "What do I know?"; that information is beyond the scope of the original study on which the guidelines are based (Jones, 1993). However, we do present the following issues associated with the question of "What do I know?" as a suggestion for where future research on the integration of interface design and metacognition might be focused.

The user interface can indicate the content covered in the program through the use of advance organizers such as menus. It can indicate the content covered by users through selection indicators, such as highlighting choices, placing check marks on menu items after they have been selected, or any like mechanism to indicate to users that they have been through the material. One traditional problem associated with marking selected sections is that indicating that a section has been selected does not mean that the users have studied all of the information in that section. Accessing information does not automatically mean that the information has been studied and processed by the users.

Providing for "self-evaluation" methods within the computer-based learning environment is also a way for users to check what they know. Long represented in CBI as testing exercises such as "Check Yourself" or "Final Tests," these types of evaluations make it possible for users to gain information on how much they have learned through the use of the program. In a linear tutorial, designers can provide users with a standard set of questions which can be used to check one's progress and performance. However in a complex environment such as a computer-based learning environment where users define their own problems, individual users may take different paths and find and study different types of information. Providing for "self-evaluations" in these types of environments may require different types of exercises than we are currently familiar with. And in the design of the computer-based learning environment, this can translate into a significant programming task. Once again, this an area of interface design where designers and developers need to work together to push the proverbial envelope of what can be done.

Regardless of what type of testing or evaluation exercises are used, users will need notification of correctness to various responses. Once again, tradition and tools have often dictated the use of easy to define and check multiple choice questions. However, to provide users with realistic self-evaluation mechanisms, it will be necessary to design and develop new and different testing strategies. We recommend this as an area of continued research and development.

Conclusion

The area of user interface design in CBI and computer based learning environments is rife with opportunities for further study. As technology changes it becomes increasingly important for designers to put together methods for users to access information. There are many people involved in the design of user interfaces. Artists, philosophers, computer scientists, writers, and instructional technologists (Jones, 1993; Laurel, 1990) are but a few of the types of people working to make user interfaces better. Regardless of who is involved in the design of the user interface, it should never be forgotten that the purpose of the interface is to make the information contained in the program available to users. Further study on how users use programs, and what types of information are required by users can only make interfaces more effective, more efficient, and more engaging.

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Wier, A. & Lee, J.H. (1994). Lets learn ergonomics. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 193-200). Nashville, Tennessee: Omni Press.

Lets Learn Ergonomics

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Abstract: *Let's Learn Ergonomics* is courseware developed originally as a Masters Project by Jong Ho Lee (M.A. 1992) of the Department of Industrial Design at The Ohio State University. Asst. Prof. Alan Wier, the major faculty advisor on the project has continued to refine the courseware based on two formative evaluations. The *Let's Learn Ergonomics* courseware was created using Authorware Professional (v. 1.7 on the Macintosh platform). The Masters Project version was completed in May, 1992.

The *Let's Learn Ergonomics* courseware was designed to teach undergraduate industrial design students the basic concepts of the ergonomic design process. The courseware development process was: preliminary investigation, problem identification, project goal establishment, instructional system design, program development and formative evaluation.

The following paper is a summary, prepared by Alan Wier, of Jong-Ho Lee's Master's Candidate Thesis.

Preliminary Investigation

The preliminary investigation was conducted between September 1991 and March 1992. It reviewed and analyzed existing ergonomic data sources and existing teaching methods and techniques to identify strengths and weaknesses.

Summary of Ergonomic Data Sources

Review and analysis of existing Human Factors references were conducted to identify the specific problems of the Human Factors information sources. Problems were identified in three categories: awkward representation of Human Factors data, poor Human Factors design application examples, and poor Human Factors hands-on examples.

With respect to data representation in the existing Human Factors data sources, the investigation reveals that not all the data were presented in the form most appropriate for use by the designers. The excessive use of statistical analysis terminology and technical jargon in data tables and charts was a typical example of the awkward data representation category. Human Factors data should be presented in the form that most designers can extract valuable information without difficulties.

Poor application and hands-on examples in the existing Human Factors references were identified as problems of Human Factors information sources. Not providing complete explanations for design standards in application and hands-on examples caused confusion to the users. Human Factors design sources should provide enough application and hands-on examples with clear explanations.

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Summary of Existing Human Factors Instruction

Analysis of existing Human Factors instructions was conducted during Autumn 1991 and Spring 1992 in the Department of Industrial and Systems Engineering and in the Department of Industrial Design at O.S.U. Instructional problems which were identified during the investigation could fall into three categories: 1) insufficient instruction for the reliability of various Human Factors data sources for industrial design students, 2) insufficient instruction for Human Factors data interpretation for industrial design students, 3) poor Human Factors application examples within the instruction and 4) poor Human Factors hands-on examples within the instruction.

Insufficient instruction regarding the reliability of various Human Factors data sources was identified as a problem of the ID course. Good Human Factors instruction should provide a list of available anthropometric sources and a review of the sources. Insufficient instruction regarding data interpretation was identified as a problem. Good Human Factors instruction should provide various statistical Human Factors data interpretation methods to design students so that they can use Human Factors data for their purpose. Finally, poor Human Factors data application examples and hands-on examples were identified as problems. Human Factors application examples and hands-on examples appropriate to design students should be provided by the instruction. Through these examples, students can learn various Human Factors design strategies.

Problem Statement

This investigation led to the problem identification. During class projects, industrial design students experienced a variety of difficulties as they attempted to use Human Factors data and methods during their design development process. Feelings of frustration and hesitation which arose from these difficulties caused the students distress in using Human Factors data and methods for their design development.

The existing Human Factors information sources available to industrial design students were 1) Human Factors data sources and 2) Human Factors instruction. These two information sources were reviewed and analyzed for a clear understanding of the problem. The problem was categorized into five groups and they were as follows:

1. Insufficient instruction regarding the reliability of Human Factors data sources.
2. Awkward representation of Human Factors data within Human Factors data sources.
3. Insufficient instruction regarding Human Factors data interpretation.
4. Poor Human Factors design application examples within Human Factors data sources and provided by instruction.
5. Poor Human Factors hands-on examples within Human Factors data sources and provided by instruction.

Project Objectives

With these identified problems in mind, project goals and objectives were established. Criteria for 'good' ergonomic instruction were also devised. The goal of the study is to develop an instructional system that can resolve the problems identified in the previous section. The objectives of the study are:

OBJECTIVE 1: To design an instructional system that provides an instruction regarding the reliability of Human Factors data sources.

OBJECTIVE 2: To design an instructional system that improves the quality of the representation of Human Factors data sources.

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OBJECTIVE 3: To design an instructional system that provides an instruction regarding Human Factors data interpretation.

OBJECTIVE 4: To design an instructional system that improves the quality of application examples.

OBJECTIVE 5: To design an instructional system that improves the quality of hands-on examples.

Instructional Goals, Objectives, and Lessons

Next, an instructional system was designed based on project goals, objectives, and criteria. Theinstructional system built up a series of goals, objectives and lessons. The decision was also made at this time to develop a computer based courseware program. Industrial design students will perform various Human Factors design activities. The program was then developed based on these instructional goals, objectives, criteria and expert input.

The following section describes examples of an instructional goal and performance objectives for Human Factors instruction. The instructional objectives are based on objectives of this project. The project objectives led to the instructional goal establishment.

GOAL 1.0: (Intellectual Skills)
Industrial design students will identify a list of Human Factors data sources.

GOAL 2.0: Industrial design students will read Human Factors data correctly.
Objective 2.1 (Intellectual Skills)
Industrial design students will identify the concept of various statistical analysis methods.
Objective 2.2 (Intellectual Skills)
Industrial design students will identify various Human Factors terminology

GOAL 3.0: Industrial design students will interpret Human Factors data correctly.

Objective 3.1 (Intellectual Skills)
Industrial design students will recognize the characteristics of statistical analysis methods used in Human Factors data sources.

Objective 3.2 (Intellectual Skills)
Industrial design students will recognize the meanings of various Human Factors terminology.

GOAL 4.0: Industrial design students will learn Human Factors design strategies through application examples.
Objective 4.1 (Intellectual Skills)
Given row anthropometric data charts and tables, students will demonstrate their understanding of different Human Factors design strategies by answering a given question.
Objective 4.2 (Intellectual Skills)
Industrial design students will recognize the characteristics of Human Factors design strategies through application examples.

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Objective 4.3 (Cognitive Strategy)

Industrial design students will adopt Human Factors design strategies through application examples.

GOAL 5.0: **Industrial design students will experience Human Factors design process through hands-on examples.**

Objective 5.1 (**Intellectual Skills**)

Industrial design students will demonstrate their understanding of Human Factors design process by answering a given question.

Objective 5.2 (Cognitive Strategy)

Industrial design students will adopt Human Factors design process through hands-on examples.

GOAL 6.0 (Attitude)

Industrial design students will be encouraged to choose to use Human Factors basic data and design methods.

GOAL 7.0 (Attitude)

Content Development

A major concern of the program development was to develop an instructional system that solves the problems identified in chapter I. The problems were: data source access problem, data representation problem, data interpretation problem, poor application examples problem, and poor hand-on analysis examples problem. The first version of the script had been developed during Spring 1992 was based on these concerns. In the development process, the instructional goals and objectives served as a spring-board to concepts development.

The courseware was built around the tasks associated with the ergonomic research, analysis and problem solving involved with designing a sit-down fork-lift truck. A fork-lift truck was introduced in the script development process for: 1) providing good application and hands-on examples, 2) drawing design students' attention, and 3) providing a mean of changing student's attitude toward Human Factors. First of all, a fork-lift truck design can provide good application and hands-on examples because it involves various Human Factors design activities such as access to anthropometric data; interpretation of the data; searching for Human Factors design strategies; field study process; and design analysis. Secondly, industrial design has been played a major role in the development of the equipment and a fork-lift truck design can attract design students because the industrial equipment industry is a potentially attractive job market to industrial design students. Thirdly, a fork-lift truck design example can change students' attitude toward Human Factors by demonstrating that Human Factors can be easily applied to the product development process by designers.

The script was evaluated by Human Factors educators, namely Alan Wier, Joseph Koncelik and Mohamad Parnianpour. Based on this evaluation, the program was revised and implemented during Spring 1992. The interface guidelines, which were established previously, also played an important role in developing the program interface.

Overview of Content

An overview of the program content of "Let's Learn Ergonomics." The program is composed of three major sections and 14 divisions.

Wier, A. & Lee, J.H. (1994). Lets learn ergonomics. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 193-200). Nashville, Tennessee: Omni Press.

The three sections are:

Section 1 : Initial attitude and intellectual adjustment
- Division 1 : Job opportunity
- Division 2 : Application form
- Division 3 : Statistical terms & Ergonomic terms
- Division 4 : Briefing & Review

Section 2 : Design analysis and test
- Division 5 : Job description
- Division 6 : Your job plan
- Division 7 : Complaints
- Division 8 : Field Study

Section 3 : Applying Human Factors data to product
- Division 9 : Measuring truck
- Division 10 : Take body data
- Division 11 : Comparison strategy
- Division 12 : How much change
- Division 13 : Z-score
- Division 14 : Recommendations

In the program, users "apply" for a job with Crown Equipment Corporation, an actual manufacturer of material handling equipment. They then complete the necessary training to become qualified to do ergonomic field research. After completing the field research, the user is presented with evaluation formulas and application strategies commonly used in ergonomic design. Finally, the user makes recommendations for design changes in the truck, based on the earlier field research, evaluation formulas, and application strategies.

The first formative evaluation was conducted by Jong-Ho Lee during Spring, 1992, as part of his Masters Project. The second formative evaluation was conducted by Robert Jennings, a graduate student in design education, during Autumn 1992. Both evaluations utilized students and experts to measure the effectiveness of the program. Instructional goals and objectives were used as criteria for the evaluation. The evaluation was based on analysis of data gathered from student and expert responses to a formal instrument, observation of students using the program, and interviews. Conclusions were drawn from this evaluation. Recommendations for further modification were derived from those conclusions.

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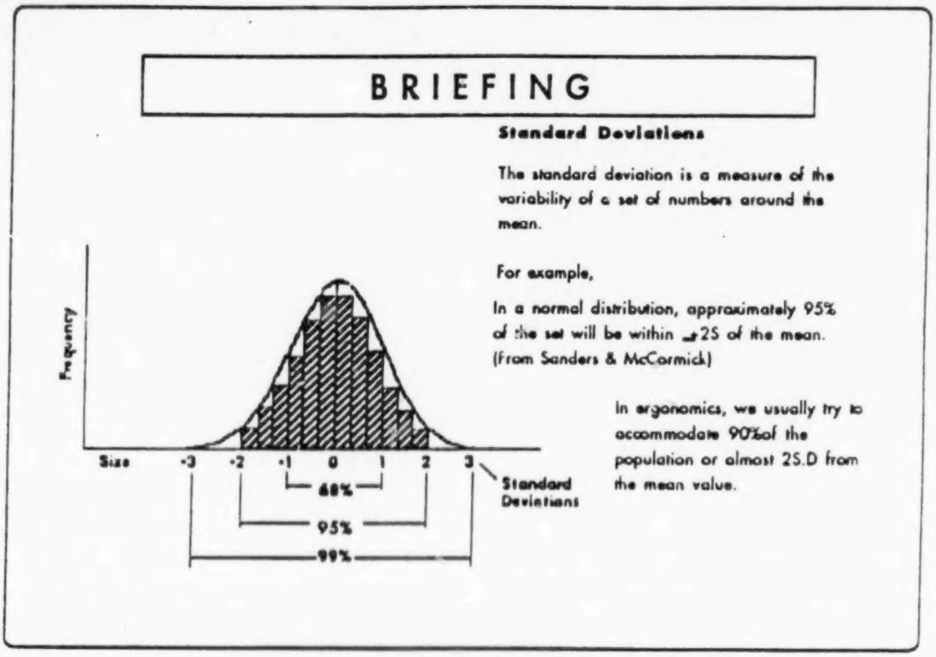


BRIEFING

Standard Deviations

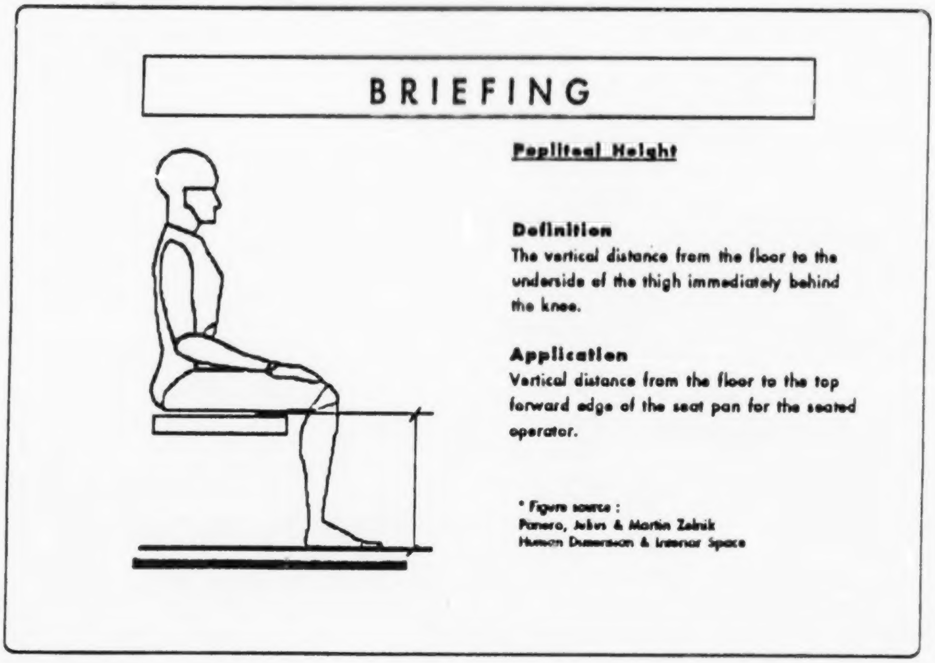
The standard deviation is a measure of the variability of a set of numbers around the mean.

For example,

In a normal distribution, approximately 95% of the set will be within ±2S of the mean. (From Sanders & McCormick)

In ergonomics, we usually try to accommodate 90%of the population or almost 2S.D from the mean value.

Figure 1) Division 4 : Standard Deviations



BRIEFING

Popliteal Height

Definition
The vertical distance from the floor to the underside of the thigh immediately behind the knee.

Application
Vertical distance from the floor to the top forward edge of the seat pan for the seated operator.

* Figure source :
Panero, Julius & Martin Zelnik
Human Dimension & Interior Space

Figure 2) Division 4 : Popliteal Height

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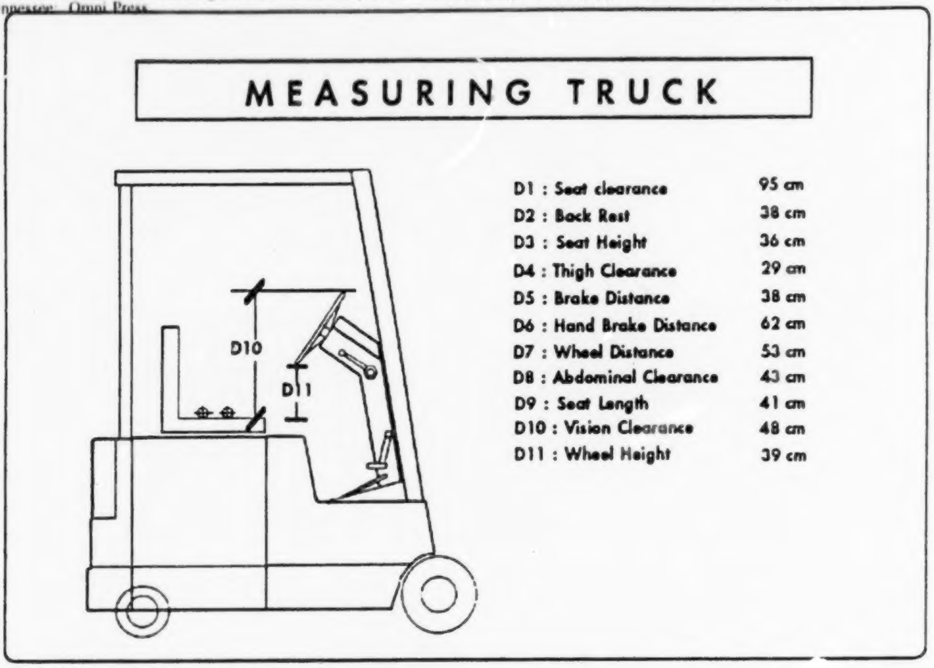
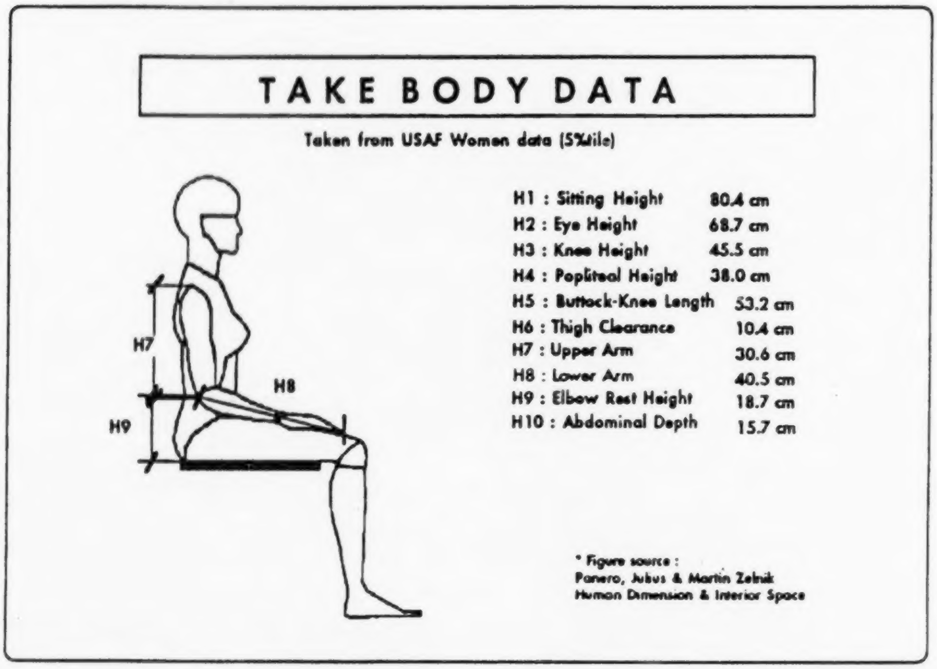


MEASURING TRUCK

D1 : Seat clearance	95 cm
D2 : Back Rest	38 cm
D3 : Seat Height	36 cm
D4 : Thigh Clearance	29 cm
D5 : Brake Distance	38 cm
D6 : Hand Brake Distance	62 cm
D7 : Wheel Distance	53 cm
D8 : Abdominal Clearance	43 cm
D9 : Seat Length	41 cm
D10 : Vision Clearance	48 cm
D11 : Wheel Height	39 cm

Figure 3) Division 9 : Measuring Truck



TAKE BODY DATA

Taken from USAF Women data (5%tile)

H1 : Sitting Height	80.4 cm
H2 : Eye Height	68.7 cm
H3 : Knee Height	45.5 cm
H4 : Popliteal Height	38.0 cm
H5 : Buttock-Knee Length	53.2 cm
H6 : Thigh Clearance	10.4 cm
H7 : Upper Arm	30.6 cm
H8 : Lower Arm	40.5 cm
H9 : Elbow Rest Height	18.7 cm
H10 : Abdominal Depth	15.7 cm

* Figure source :
Panero, Julius & Martin Zelnik
Human Dimension & Interior Space

Figure 4) Division 10 : Take Body Data

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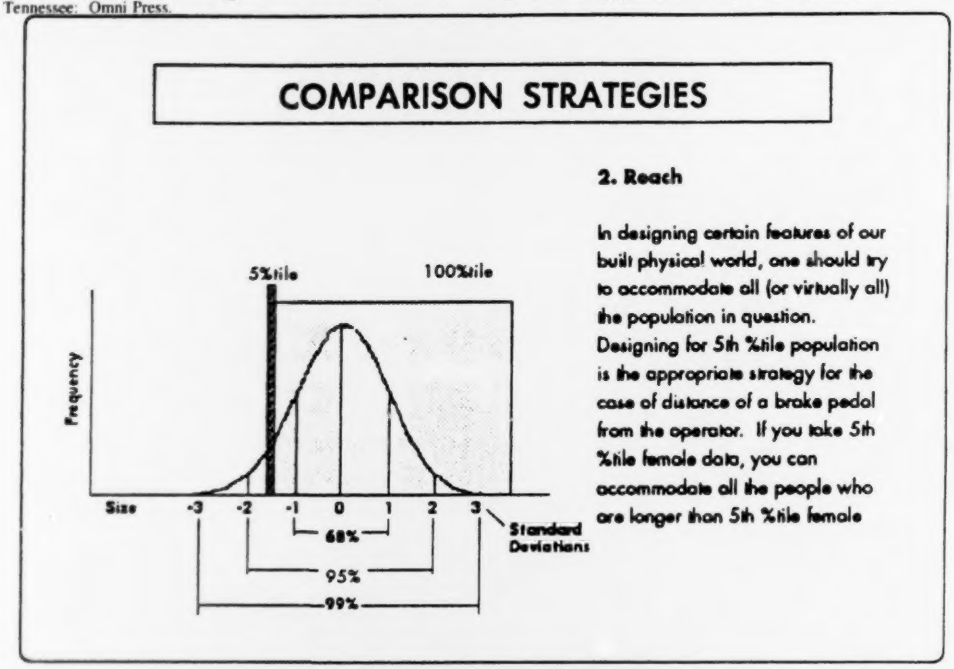
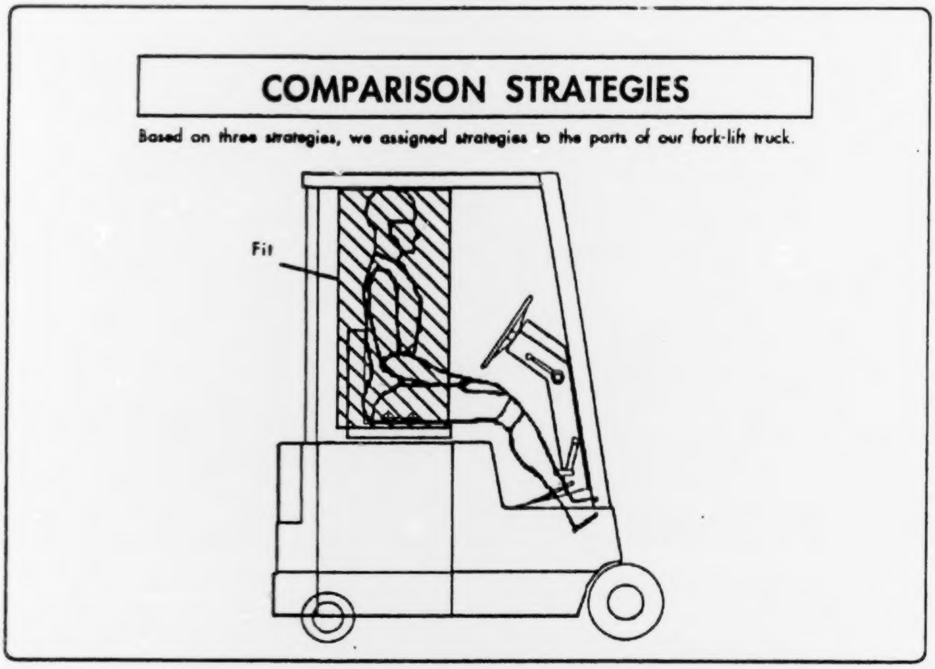


COMPARISON STRATEGIES

2. Reach

In designing certain features of our built physical world, one should try to accommodate all (or virtually all) the population in question. Designing for 5th %tile population is the appropriate strategy for the case of distance of a brake pedal from the operator. If you take 5th %tile female data, you can accommodate all the people who are longer than 5th %tile female

Figure 5) Division 11 : Comparison Strategies > Reach



COMPARISON STRATEGIES

Based on three strategies, we assigned strategies to the parts of our fork-lift truck.

Figure 6) Division 11 : Comparison Strategies > Fit

Sweeters, W. (1994). Developing computer-based learning courseware in a large institution. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 201-206). Nashville, Tennessee: Omni Press.

Developing Computer-Based Learning Courseware in a Large Institution

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Abstract: A survey of experienced CBL developers in a large institution was undertaken to determine their perceptions of the best and worst uses of CBL development, the perceived blocks to development and perceptions of the difficulty in implementing the various phases of the CBL courseware development process.Recommendations for managing and developing CBL courseware are included.

Introduction

The advent of multimedia has brought new and exciting capabilities to computer-based learning. With its accessibility and huge storage capacity, CD ROM technology has enabled us to create multimedia programs which are powerful educational tools for use on personal computers.Many organizations and institutions will want to develop computer-based learning tools enhanced with multimedia. How should they go about this?.

This paper presents a study dealing with factors which have effected the development of CBL courseware at The Singapore Polytechnic, a large technical institution serving over 13,000 students in ten technical departments. As Director of The Centre for Computer Based Learning (CCBL) the author managed a courseware development process with a core of five Centre staff members.The major source of input to the development of courseware came from the 600 lecturers of the Polytechnic.

In 1987 the CCBL was established at the Singapore Polytechnic. Since then, the CCBL has promoted the development of courseware by holding seminars and conferences and establishing a network for interested staff. The Centre has established a development process and offers staff training in courseware design and authoring languages. Over 200 staff have attended Centre courses and about 150 courseware projects were attempted over the years. In addition, the Centre manages projects by conducting meetings and reviews with staff and setting production schedules. The Centre is currently overseeing about 15 courseware projects each year.

The findings of this survey should be useful to any organization attempting the widespread development of electronic learning courseware, using staff members as the primary developers.

Methodology

A survey was sent to 73 staff members who had completed a CBL courseware project within the past two years or were supervising an active script. After a follow-up notice, valid responses were received from 40 staff while 10 staff were found to have left the institution.

In order to validate the survey results by triangulation, an additional means of communication was used to obtain the same type of information. Telephone interviews were conducted with a random sample of 15% of the total group.

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Findings

The survey covered three areas of concern:

What is the best & worst use of CBL courseware?

What are the blocks to development of CBL courseware?

How difficult are the phases of the CBL courseware development process?

Findings are reported by area of concern.

What is the best & worst use of CBL courseware ?

Best Use

The most common reported best use of CBL courseware is as a supplement to the lecture/ tutorial and as a teaching aid.

The next most commonly reported best uses of CBL courseware are to provide individual student access to material, as remedial help, for revision/ study before exams or as a make-up for students who have missed instruction.

Other best uses of CBL courseware are to stimulate student interest in a topic, as a pre-lab exercise to help students prepare for lab work and to replace paper and pencil exams.

In addition, a few staff indicated that CBL was best used for -

- teaching 'the basics'
- teaching theory
- for simulations and
- for practice questions.

Worst Use

A majority of the respondents indicated that using CBL courseware to replace the teacher is the worst way to use CBL.

Additional worst uses included using CBL to replace practical lab work and to simply present information, e.g., as an electronic page turner.

Other worst uses included using CBL to teach psycho-motor skill development and for drill and practice.

A few staff replied that a worst use was **not to use it at all!**

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What are the blocks to the development of CBL courseware?

Figure 1 shows the blocks to development.

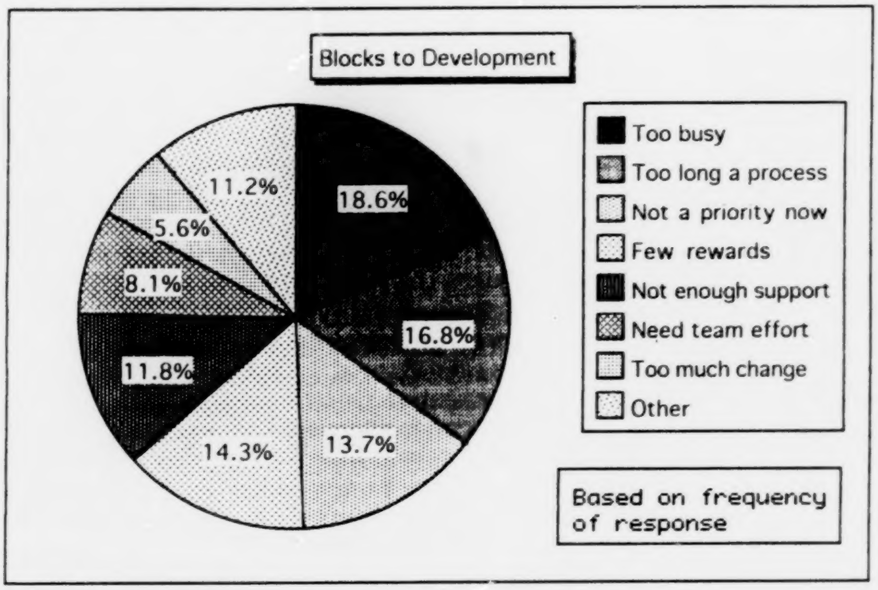

Figure 1. Staff reports of blocks to the development of CBL courseware

Too busy and too long a process
The major blocks to CBL development are the lack of time available to undertake a courseware project and the length of time required to complete a project. These are not surprising findings since lecturers often have over 22 student contact hours each week. Assuming only one hour preparation for each contact hour results in a 44 hour work week.
In addition, staff have duties on committees, sports programs, counseling and a number of special projects to develop, conduct and manage. There appears to be little time left to undertake a CBL development project.

In addition to the lecturers lack of time for undertaking projects is the great length of time needed to develop CBL courseware-- 250 hours to develop a 1 hour lesson is common. It typically takes 6 months to a year to produce a lesson. Nevertheless, Polytechnic staff have been producing about 15 courseware per year.

Not a priority now and too few rewards
Some staff reported that CBL development was considered a low priority compared to their other duties. Staff also indicated that there were few rewards given for producing courseware.

Not enough support
Staff mentioned a need for facilities to support CBL development. Staff need ready access to computers in their offices and homes.

Computer loans and special staff discounts can be negotiated when institutions place large orders for computers.

Students also need ready access to view computer-based courseware. Booking terminals in computer labs is often troublesome to students - computers and software need to be available campus wide. Resource centers in libraries,lounge areas and dormitories can provide the required student access to computers.

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CBL development requires a team approach

Staff indicate that a team approach will ensure that topics chosen for CBL development will be integrated into the curriculum. Staff also mentioned that some curriculum management committees are not even aware of CBL capabilities.

In a particular course, one hour of CBL is not likely to have much impact but 10-20 hours of CBL can provide enough variety and focused skill development to significantly improve student motivation, interest and achievement. A team approach can provide a more focused plan for CBL development and by getting more people involved in development, more CBL courseware can be produced for greater impact.

Syllabus changes too fast

Some staff developed courseware on topics that were later dropped from the curriculum. Others have developed courseware for their courses and then been reassigned to different courses. Such experiences have discouraged staff from developing CBL.

If CBL projects were planned by a team effort and coordinated through curriculum management committees then topics likely to be dropped or modified could be identified and rejected as candidates for CBL development

How Difficult are the Phases of the CBL Development Process?

Figure 2 shows how staff rated the difficulty of each phase of the development process.

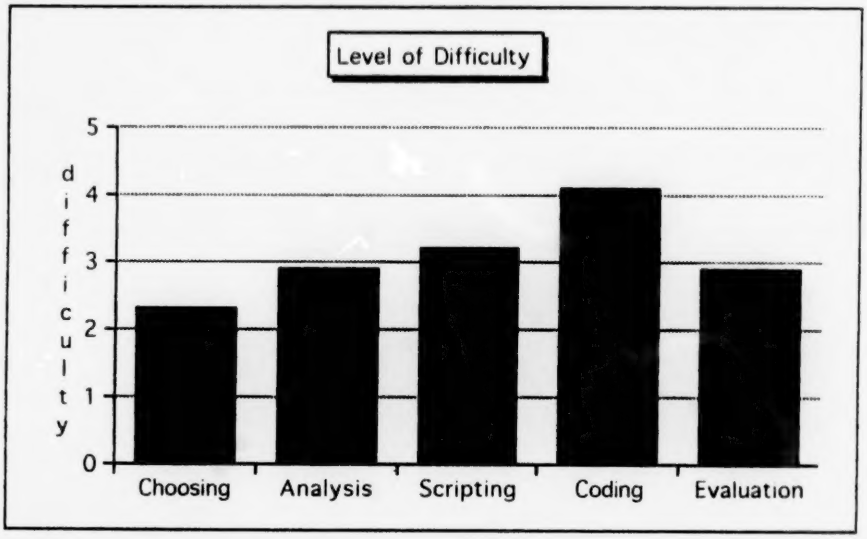

Figure 2. Level of difficulty for each phase of the CBL development process

As might be expected, coding courseware is perceived to be the most difficult phase of development by the staff. The other phases of development fall in mid-range and are viewed as neither particularly difficult or easy. Scripting is rated as the second most difficult activity and no phase is considered easy.

Indeed, coding requires programming skills which are often quite alien to lecturers. In the normal course of preparing for classes the skills of choosing topics, analyzing content, writing lecture notes and evaluation are utilized but programming skills are not required. Coding is a bottleneck in the development process and must be addressed. The Centre offers staff training in authoring languages and help for special coding problems but this is not enough support for most staff. The Centre has taken responsibility for much of the task of coding and codes scripted lessons by assigning projects to Centre staff, hiring programmers, hiring external consultants to code and using students to code lessons as project work in their field. Students have been especially keen on coding courseware as they enjoy

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working with an authoring language and developing computer graphics. Staff report that because of our support in taking over much of the burden of coding, they are more motivated to embark on CBL development.

Many other blocks to CBL development may not have surfaced in this study because they have been anticipated and addressed by Centre staff. The Centre offers courses in CBL design and authoring languages, models for development, screen design guidelines and regular reviews with staff. These activities support the development process and there was no criticism of Centre procedures. Were any of these elements missing, they might surface as additional blocks to development.

Conclusion:

Best Use of CBL Courseware

Staff suggest that the aim of CBL courseware should be to support rather than replace traditional instruction. CBL courseware can be used to deal with many of the problems associated with lecturing, e.g., remedial help for students unable to make satisfactory progress, revision/ study aid and as a make-up for students who miss instruction.

Worst Use of CBL Courseware

Staff are concerned that CBL courseware could be used to undermine the importance of the lecturer/ tutor and to replace direct teaching and laboratory experience.

Blocks to Development

Many blocks to development stem from the organizational goals of the institution. If electronic learning is promoted from the top down, it will become a priority goal. Closely related to priority goals are the rewards offered to staff who develop CBL courseware. Staff who undertake a CBL project could be allocated specific time for it in place of scheduled classes, they could be given the kind of recognition a publication brings towards merit awards or tenure, they could be given direct monetary awards for courseware used by the department and they can be given personal recognition by the department or institution. Some staff mentioned that their department heads and colleagues were not aware of the time and effort required to produce CBL courseware.

The major blocks to CBL development are the lack of time for staff to undertake a project and lack of an organizational commitment to allocate staff and resources to the goals of CBL courseware development.

Phases of Development

Coding is the most difficult phase of CBL development for staff and all phases are moderately difficult.

Recommendations

The following recommendations should be considered by any organization embarked on the widespread development of CBL courseware: using staff as a primary resource:

☆ *Provide independent coding support*

A major block to CBL development is the effort required to code courseware. It is necessary to break the coding bottleneck by providing coding assistance to staff developing CBL courseware.

☆ *Provide top down support and rewards*

An institutional commitment needs to be made to support CBL development in an organization. A rewards system for staff efforts needs to be established.

☆ *Integrate CBL development with curricula*

CBL development should not be left to the initiative of individuals. Courseware development needs to be planned with the curriculum management committee and a team effort needs to be started to ensure that a reasonable number of courseware will be developed.

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Establish a CBL development unit

CBL development within an organization needs the control and guidance provided by a development process, design guidelines, models and templates. Developers also need support such as training, reviews of their work, seminars and networks to promote ideas and motivation. They also need a representative to express their needs and concerns to departments and the organization.

Suggested Readings

Bunzel, M.J., & Morris, S.K. (1992). *Multimedia applications developments: Using DVI Technology.* New York: McGraw-Hill.

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Cates, W.M. (1994). Exploring the reasons behind design decisions: interactive multimedia learning environments. In M. Orey (Ed.), *Proceedings of the Thirty-fifth ADCIS Conference* (pp. 207-214). Nashville, Tennessee: Omni Press.

Exploring the Reasons Behind Design Decisions: Interactive Multimedia Learning Environments

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Abstract: This paper focuses on decision making in the instructional design process. In particular, it explores the key decisions made in designing an interactive multimedia learning environment (IMLE) to teach science to bilingual students in 7th to 11th grades. Key decisions include handling content area instructional demands, selecting metaphors and images, reducing cognitive load, supporting learners through help, advisement, and coaching, and selecting appropriate features and capabilities. Attaining a balance between direct instruction and learner exploration and experimentation is also addressed.

As Mountford (1990) noted, "There are few success stories for interface designers to learn from" in the field of instructional design (p. 18). In the absence of success stories, she suggested that designers share the results of their efforts with one another. There is no formula for `good' design. Design is a creative process based on carefully reasoned decisions. Too seldom, however, do designers discuss the reasons behind their decsions. This paper discusses the design of an interactive multimedia learning environment (IMLE) for teaching science to seventh through eleventh graders in learning situations where students may have as their first language either English or Spanish. I have used the Jason Project as the basis for a proof-of-concept demonstration, illustrating how some of the concepts in the design might be implemented using material from that project, and this paper uses examples from that proof-of-concept treatment[1]. The paper is organized around a series of questions, the answers to which explain why the product under design looks and operates as it does.

IMITATE OTHERS OR BUILD ANEW?

When asked to design a new product, one has two choices: One can imitate some previously designed piece of software or one can create a new design from scratch. When designers have done careful and creative design, others can benefit from adopting their decisions. Similarly, if users have become accustomed to those designs, they should have less difficulty adjusting to products employing similar designs. Like many products on the market, the current product chooses to employ some common elements of other designs, including the use of a control strip of icons which makes available to users a variety of functions (Iuppa & Anderson, 1988), electronic journal capabilities (*Civil War Hypermedia Project Design Document*, 1991), on-line context-sensitive help (Sellen & Nicol, 1990), and the ability to leave the program and restart at the same point (Brown, 1988). The control strip is familiar to many users and seems likely to help users think of the functions on the strip as a visual entity. That is, the visual unity of the strip may help users perceive it as a whole, thus helping to group it as a single `chunk,' reducing the cognitive load on the user (Miller, 1956). The electronic journal permits users to record thoughts as they occur to them and to make notes as they deem necessary. This, too, should increase the sense of learner control and reduce the cognitive load that memorization or attempting to perform actions while recalling one's own thoughts may impose (Oren, 1990). On-line context-sensitive help should help cure the problems of user disorientation and, once again, reduce the cognitive load imposed by having to recall where one is and how one got there (Baird, 1988). The ability to leave and restart should make learners feel more in control and should help make the product better suited to the demands of instruction in settings where time may be limited (Cates, 1992).

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HOW SHOULD LEARNER NEEDS BE SUPPORTED?

Hutchings, Hall, Briggs, Hammon, Kibby, McKnight, and Riley (1992) argued that "*raw* hypermedia is not sufficient to support effective learning. Educational hypermedia must be able to support a variety of interaction/learning styles" (p. 177). Jonassen and Grabinger (1990) and Nicol (1990) concurred, suggesting that hypermedia designed to facilitate learning outcomes needs to address learners' information processing and the demands of the tasks they are trying to accomplish. Spiro and Jehng (1990) argued that, "one learns by criss-crossing conceptual landscapes; instruction involves the provision of learning materials that channel multidimensional landscape explorations under the active initiative of the learner" (p.170). Gygi (1990) expressed reservations about broad large information vistas, however, suggesting that they can be daunting. Many writers have addressed the cognitive load that large `dataspaces' place on learners (see for example, Lanza & Roselli, 1991 and Marchionini, 1988). Some, like Mitsch and Dubberly (1990) and Sellen and Nicol (1990), have suggested that conceptual maps might help learners navigate such spaces. The findings on the effectiveness of such maps have not been positive, however; it appears that they may be too complex to assist learners in any significant way (Jonassen & Wang, 1993). A second approach might be to`reduce the size of the learner's universe'; that is, to focus more on depth of coverage than on breadth of coverage and to select for inclusion only pieces of information likely to assist learners with the material at hand. This approach has received the support of a number of writers (see for example, Florin, 1990; National Committee on Science Education Standards and Assessment, 1993; Padilla, 1990 and Siviter & Brown, 1992). It is the approach used in the present product.

As noted in the previous section, one way to support learners is to make good on-line help available from every screen. This help is not intended to replace good interface design, but rather to eliminate the sorts of confusions that learners, particularly novice learners, experience when first working with a system (Carlson & Grabowski, 1992; Rheingold, 1990). Sellen and Nicol (1990) suggested that such help might supply the answers to five types of questions: What can I do here? What is this and what does it do? How do I do this? Where am I? What just happened and what does it mean? On-line help in the present product is designed to answer these sorts of questions. This type of help is normally referred to as `context-sensitive' help.

Another type of help might be called `content-sensitive' help. This would be advice or coaching based on the material available from a particular screen. Marchionini (1989), Wolz, McKeown, and Kaiser (1989), and Yordy (1991), among others, have suggested that such advice may help support learners' needs. In the present product, content-sensitive help includes advice on what to look for, advice on what scientific concepts are involved, and advice in the form of Socratic questions designed to direct the learner's thinking (Keegan, 1993; Steinberg, 1992). All content-sensitive help is presented using the language of self-attribution ("I would like. . .") to encourage a sense of learner control (Clariana, 1993; Keller, 1979). Laurel (1990) suggested that person-like guides were popular with users. As Brennan (1990) noted, people seem to bring expectations from their human to human interaction to their interactions with computers. In fact, Oren, Salomon, Kreitman, and Don (1990) found that users attributed emotional characteristics to their guides and formed `relationships' with them. In order to take advantage of this occurrence, the present product allows learners to select their guides from among a large number available, and allows learners to `interview' perspective guides/advisors before selecting them, by examining their resumes and watching a three minute video clip in which the advisor tells a little about himself or herself. Once an advisor is selected, that advisor's picture appears on every screen on an icon offering content-sensitive help and advice.

WHAT TYPES OF ACTIVITIES SHOULD BE INCLUDED?

There appear to be four main ways in which a multimedia product might be employed in instruction: (1) to deliver direct instruction, (2) for exploratory learning, (3) as a research tool, and (4) to prepare multimedia presentations (Greeno, 1991). Each calls for a different level of learner control. There is a wide body of research on learner control that suggests learners have a great deal of difficulty making choices and handling their own learning needs (Heller, 1990; Lanza & Roselli, 1991; Ross & Morrison, 1988; Santaigo & Okey, 1992). As Jonassen and Wang (1993) concluded, "merely browsing through a knowledge base does not engender enough processing to result in meaningful learning" (p.7).

Direct instruction in IMLEs is often delivered using `guided tours.' Guided tours resemble traditional classroom presentations in that they exhibit a high degree of linear structure and they usually have fairly well defined learning objectives. These properties of guided tours tend to associate them more closely with program control than learner control, although learners still have some options in most guided tours. While exploratory learning offers more opportunity for learners to have difficulty, it also gives learners the freedom to `criss-cross information landscapes,' examine materials of interest, and explore in ways that invite the learner to form serendipitous and fortuitous new connections among pieces of information. When a product is used as a research tool, it permits teachers or students to seek answers to their questions using the resources contained in the product. Once again, learners who are not experienced in such multimedia research efforts may find themselves quickly lost. When learners use a multimedia product to prepare a presentation, they are using its selection and editing features to use the resources and materials of the product to build a presentation to show others. This use appears to be satisfying to many teachers and students and has received much praise in the literature (Collins, 1991; McCormack, 1992).

The present product uses a combination of these activities. Expeditions provide the general structure; each is, at heart, a guided tour of a realistic experience, a form of anchored instruction (The Cognition and Technology Group at Vanderbilt, 1993). At the same time, each offers the learner chances to participate in simulations and to conduct experiments, in keeping with American Association for the Advancement of Science's emphasis on curiosity and hands-on science (see below). To help learners avoid getting lost in these activities, the advisor is always available to keep them on-task and on-target. Learners who don't want or need advice can choose not to call it up. The product employs a non-intrusive coach; if learners do not click on the advisor icon, the only advice they will see is that offered to all learners in on-screen instructions and in general advice from Bob Ballard (Jason Project host). The product should also offer learners the opportunity to do some unstructured exploring on their own and, like most products on the market, should offer at least minimal production facilities so that teachers and students can produce their own presentations and reports.

WHICH METAPHORS ARE APPROPRIATE?

Many authors have argued that using metaphors in multimedia products can help users, particularly novice users, understand how a product works and predict correctly how to accomplish specific actions (see for example, Allinson & Hammond, 1989; Erickson, 1990; Mitsch & Dubberly, 1990; and Rosendahl-Kreitman, 1990). In the example of a product based on the Jason Project, the underlying metaphor for most screens is the expedition, often accompanied by printed materials with illustrations. Where experiments are to be conducted, the underlying metaphor of a laboratory is employed, with its attendant tools and devices -- auxiliary metaphors (see Cates, 1994). Where simulation or exploration are to employed, the underlying metaphor is that of "real space." That is, if the exploration or simulation is to take place under water, the learner should see what the cameras reveal to a person manipulating the actual underwater vehicle. If the simulation or exploration is to take place on the surface of the water or out of the water, the learner should see whatever he or she would be able to see from the surface (for example, from a small boat following a migrating whale) or standing on the site (for example, in a rookery on the Galapagos Islands).

In terms of iconic metaphors, since the Jason Project has emphasized science on or under or the water in its expeditions, the images used for the icons echo maritime themes (Cates, 1993). For example, navigation between screens is accomplished using icons displaying images matched to how one navigates on a particular expedition: In the Great Lakes, the icons employ frigate ships facing forward or backwards. In the Galapagos, the icons employ skindivers swimming to the left or to the right. Off Baja California Sur, the icons employ the Jason underwater vehicle with its manipulative arm extended, either facing forward or backward. The image for "quit" is a skindiver returning to the surface. Since Bob Ballard serves as the host for the expeditions, his image appears on the icon learners use to obtain general explanations of how to use the product. In keeping with the product's decision to employ individual advisors selected by the learner, the image on the icon for content-sensitive advice is that of the advisor (coach, mentor) selected by the learner. In addition, the remaining icon on the control strip employs an image appropriate to the subject area material to be discussed there. Thus, when geology information is available, this icon displays an image of the earth; when information about broadcast technology is available, the image displayed is a satellite dish; when the information available is about how to pack for a trip, the image displayed is a suitcase. Baird and Percival (1989) and Gygi (1990) expressed concern that users may misinterpret the function of an icon, particularly if they are uncertain why it displays the image that it does. In keeping with the suggestions of Iuppa and Anderson (1988), Rubin and Milner (1988), and Florin (1990), icons display both images and words to help make clear their functions.

HOW SHOULD SCIENCE BE TAUGHT?

White, Fontana, and Cates (1991) argued that the design of an IMLE should be driven by the instructional demands of content, not by the technology. In keeping with that argument, this product derives much of its design from the demands of science instruction. In *Science for All Americans* (1989), the American Association for the Advancement of Science (AAAS) suggested that science instruction be changed to "concentrate on the quality of understanding rather than the quantity of information presented" (p. 145). Science instruction would be based on a model that limited the breadth of what was covered in order to allow more time to deal with it in depth and that viewed details as ways of enhancing student understanding of what they were studying, not as the basis for memorization and testing. The AAAS plan suggested that, "concepts are learned best when they are encountered in a variety of contexts and expressed in a variety of ways, for that ensures that there are more opportunities for them to become imbedded in a student's knowledge system" and argued that, "students cannot learn to think critically, analyze information, communicate scientific ideas, make logical arguments, work as part of a team, and acquire other desirable skills unless they are permitted and encouraged to do those things over and over in many contexts" (pp. 145-146).

AAAS offered eight strategies for transforming science instruction (p. 148): (1) Start with questions about nature. Work from the familiar. (2) Engage students actively. Let them manipulate and explore. (3) Concentrate on the collection and use of evidence. Students need to be able to separate the relevant from irrelevant. "Students need guidance, encouragement, and practice in collecting, sorting, and analyzing evidence, and in building arguments based on it." These activities need to lead to stimulating and interesting conclusions for the student. (4) Provide historical perspectives. Students need to learn about the twists and turns in investigation and theory, about the role individuals play in scientific advancement, about "the interplay between evidence and theory over time. . . . History is important for the effective teaching of science, mathematics, and technology also because it can lead to social perspectives -- the influence of society on the development of science and technology, and the impact of science and technology on society." (5) Insist on clear expression. Poor communications skills can confound inquiry and reporting. (6) Use a team approach: "Scientists and engineers work mostly in groups and less often as isolated investigators. . . . In the context of team responsibility, feedback and communication become more realistic and of a character very different from the usual individualistic textbook-homework-recitation approach." (7) Do not separate knowing from finding out: "In science, conclusions and the methods that lead to them are tightly coupled. The nature of inquiry depends on what is being investigated, and what is learned depends on the methods used." (8) De-emphasize the memorization of technical vocabulary. Introduce technical terms only as needed and gradually help students build up a vocabulary of used and demonstrated terms rather than having them memorize isolated listings of terms.

The product attempts to meet the spirit of AAAS' goals and to implement the strategies presented above. The design strategies for accomplishing this are discussed in the next four subsections.

Addressing the Way Scientists Think and Work

Instead of memorization, the product uses frequent manipulation and experimentation with repeated exposure to the key terms and materials. A glossary of science terms is always available and definitions are stated in plain English (or plain Spanish). Students do not have to go through lots of direct instruction before moving on to manipulation and experimentation. Learner creativity and curiosity are encouraged, as is a practical orientation. For example, upon selecting an expedition on which the learner wishes to go, he or she is first asked to pack his bag, paying attention to the demands of the region and the weight restrictions of travel. Scientists are portrayed as hard working, persistent, creative, and practical. Learners are exposed to creative solutions to scientific questions and anecdotes and stories that illustrate scientific creativity. Examples illustrate how an understanding of science can help us explain, understand, and predict phenomena, and learners are faced with practical problems and explorations on each expedition that encourage them to deduce the value of science.

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The product emphasizes the fact that scientists are members of a larger community, and that this community, through peer evaluation and cooperation, protects against unwarranted assumption or interpretation. The product makes it clear that there is much disagreement in the scientific community, and that disagreement is viewed as a healthy part of the peer evaluation process. The product points out that many now-well-accepted concepts initially had much difficulty gaining acceptance and helps to show that debate helped to facilitate acceptance. The product highlights controversy and disagreement, emphasizes point-of-view, and illustrates vested interest. In some exploratory activities, students are asked to assume roles or to work on scenarios that help them experience the drive to seek "desirable" results or findings. The product illustrates through examples the changing acceptance of scientific theories and concepts. Students are asked to consider and explore ethical issues in science, including the need for and use of intrusive practices (like dissection). To help students recognize the role of models and systems, the product uses technological tools as examples of systems with sub-systems. It also uses ecological systems and sub-systems to make the point. The product demonstrates how models can be used to explain occurrences, and asks students to use models to make predictions. The relationship between change and stability is used to help students recognize the larger patterns in events.

Making Instruction Match the Demands of Science

The product asks the student to form and test hypotheses, collect and analyze data, and draw conclusions. Its advisors attempt to provide the same sort of intellectual and instructional support that good teachers of science provide. The product should supply enough activities to meet or exceed the typical curricular emphasis placed on this type of material, thus permitting teachers and students to use as much, or as little, as their schedules permit. Some of the product's activities are individual learner activities, some are small-group activities, and some are computer-assisted whole-class activities. To foster a greater sense of collaboration and peer evaluation, the product uses simulated "e-mail" among teams, to and from individual students, and between the teacher and students or teams. The product provides screens in which learners are required to 'construct' tools from parts available and then to manipulate these tools to collect and analyze data. The product provides simulated 'real-world' experiments, accompanied by appropriate comments and video segments involving scientists. Students are encouraged to keep a journal, to update it often, to reflect on the currency of previous entries, and to note questions as they occur. Advisors stimulate learners to make entries in their journals and to propose both hypotheses and conclusions.

Helping Students Understand Science's Role in Society

Where appropriate, the product explores how societal opinions about the relative worth of different people, events, ideas, and objects in our society change. It notes that all peoples have both noble and ignoble records of societal development in their evolutions, and illustrates how opinions have changed and addresses specifically how society's change contributed to or impeded change in scientific opinion. The product makes clear that there are conflicting, strongly-held, and often logical opposing opinions on many scientific issues. Students are encouraged to form their own opinions, to articulate them clearly, and to defend them in the face of opposition. Once learners have formed their opinions, the product may introduce dissonant information to challenge those opinions. Students are guided to see that, in real life, there are few easy answers.

Addressing Technology's Role in Science

The product explores how improved technology can produce improved data and how those, in turn, can produce improved findings and interpretations. Simulations and manipulations help students see the value of new technologies themselves. Manipulations, simulations, and explorations often call for an engineer and a student serves in this capacity, learning in a practical setting about the interaction between engineering and science. Through direct instruction and explorations, the product examines some of the side effects of technological development. Some of the events in which students participate experience technological failures, sometimes of a sub-system to reinforce the concept of sub-systems. The product offers both complex technological solutions and simple technological solutions with accompanying failure rates in order to help students appreciate the influence of Murphy's Law. In some simulations, students find themselves faced with decisions precipitated by technological advancements. They are asked to realize the difference between "technology permits us to do this" and "it is the right thing to do" (Baez, 1991). For example, should we remove bodies from a sunken ship? Should we eradicate the mosquito?

HOW CAN THE PRODUCT ADDRESS DIVERSITY?

Much science instruction does not appear to expose girls to strong female role models in science education, role models that may help girls envision themselves as scientists (Hudley, 1992). In some science classes girls appear to be treated differently than their more aggressive male classmates and may end up as watchers rather than doers (Potter & Rosser, 1992). In classes where memorization of specialized vocabulary constitutes much of the instruction, Spanish-speaking ESL students may find themselves similarly allocated to a secondary position (Warren, Rosebery, & Conant, 1989) Girls may approach things more collaboratively than boys and teachers may be rewarding boys for competitive behaviors not necessarily reflective of practice in real-world science settings (Kay, 1988).

In order to play on the need for positive role models, the product allows learners to select advisors/guides according to their own personal preferences. Some advisors/guides are female, some are African-American, and some are members of Spanish-speaking cultural groups. All science advisors/guides should be charismatic and intellectually attractive. In all video segments and scenarios, female, African-American, and Spanish-speaking students are portrayed as "doers" of science, not "watchers" or "assistants." The product encourages both cooperation and competition in its activities. This should not only help students learn that most scientific accomplishments occur because of collaboration, but may help female students see a new role for themselves in science (Adams & Hamm, 1990; Stephenson, 1992).

The product is bilingual (Spanish-English, English-Spanish) in its delivery. The product does not relegate Spanish to the "translated version for 'English-impaired' students," but instead portrays Spanish-speaking scientists as capable and important members of the world scientific community. This should help Spanish-speaking students see themselves as having a proper place in that community. The product can convert all text to Spanish if so desired, including both screen text and audio soundtracks. The product presents all learners with some bilingual skills, teaching Spanish vocabulary as appropriate in order to help all learners understand the Spanish place names (for example, *Las Tortugas*), descriptive labels (for example, *punta, isla, laguna*), and making presentations for Spanish-speaking people (for example, the dedication in Spanish by the Ecuadorian officer on the repatriation of the iguanas) that are associated with the scientific explorations. As non-Spanish-speaking students work with this product, they should gain useful vocabulary and a sense that knowing such vocabulary expands their knowledge and helps them to become members of the world's scientific community. As Spanish-speaking students work with the product, they should see themselves at a slight linguistic advantage (for a change) and should feel some sense of pride in their bi-cultural membership (DeVillar & Faltis, 1991; Scheel & Branch, 1993). This pride may, in turn, enhance their pride in Spanish-speaking members of the scientific community as well as help them to recall that (1) much of the world speaks Spanish, (2) many places were discovered, explored, and named by Spanish-speakers, and (3) the practice of science is as active in Spanish-speaking countries as it is in the rest of the world (Bentley & Ditchfield, 1989). Similarly, where possible, the product utilizes appropriate examples of African and African-American contributions to science (Bailey, 1990).

WHAT NEXT?

As noted earlier, the product described in this paper is in the design stage. As this paper demonstrates, the process of design requires much careful thought, and additional work with bilingual instructors and subject-matter experts should help to enhance the final product. For an instructional product to make it to market, it must have an audience, there must be an instructional need, it must be well designed to meet that need, it must demonstrate to its potential users that it is a useful product, and it must acquire the necessary funding. The next step for this design is to create a small prototype and test the design on users. The journey from design to market is not free of its own set of perils. With careful planning, hard work, and a little bit of luck, this design may survive the trip.

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A GUIDED APPROACH TO INSTRUCTIONAL DESIGN ADVISING

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Abstract: Researchers are developing automated instructional design systems which guide subject matter experts (SMEs) through the complexities of courseware development (Spector, 1993). Enabling SMEs to perform many of the authoring activities associated with courseware development has two distinct advantages: (1) costs are contained, and (2) SMEs can make optimal use of new technologies. This paper will focus on a research effort called the Guided Approach to Instructional Design Advising (GAIDA). GAIDA incorporates case-based reasoning in a hypermedia framework in order to convey instructional design expertise to novice courseware developers. The paper reviews the theory and development of GAIDA, including interim results of an extensive evaluation effort.

As computer-based instruction (CBI, to be interpreted broadly) has matured, automated environments to support instructional design and development have become commercially available. At the same time, computer-based technologies have become richer and more complex with the advent of such advanced interactive technologies as digital audio/video, interactive simulations, and virtual worlds (Spector, 1990).

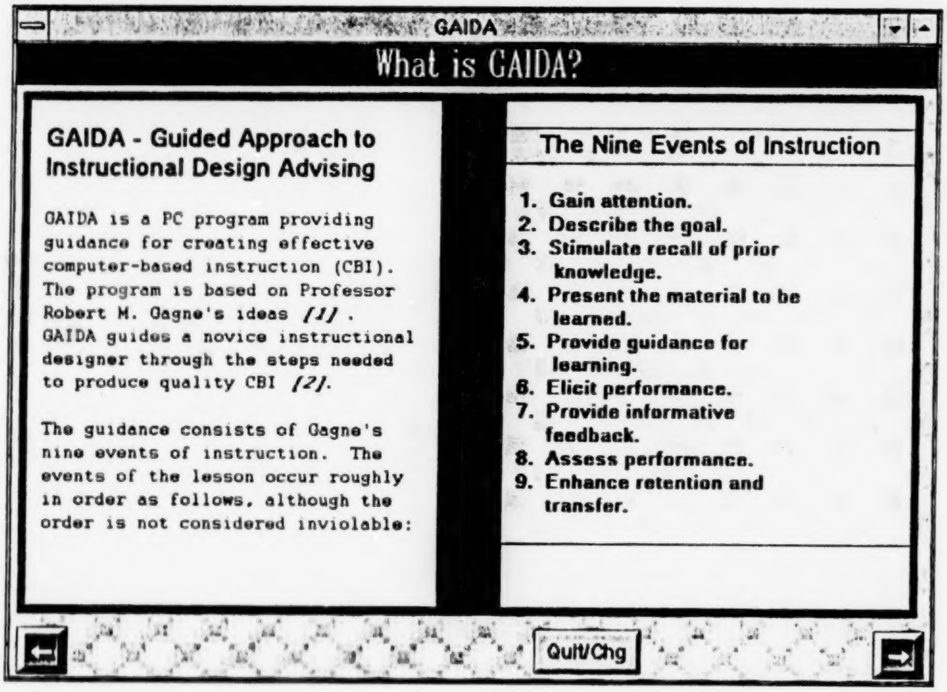
As a consequence, an organization which has the task of producing CBI must confront two difficult issues: (1) where to obtain the expertise required to produce quality CBI; and (2) how to make it cost-effective to produce a variety of CBI solutions to satisfy various training requirements. There is an industry-wide shortage of instructional technology expertise, which makes a near-term solution to the first issue difficult. Automated tools are expected to provide some support for the second issue. The system described in this paper, Guided Approach to Instructional Design Advising (GAIDA) represents an attempt to respond to both problems (Merrill, Li, & Jones, 1990).

A Theoretical Framework

An attempt to capture instructional design expertise in an automated system must address these two fundamental issues: (1) What distinguishes novices from experts in this particular domain? and (2) What is the purpose of the design advisor? With regard to expert-novice differences, the expectation based on findings in cognitive science is that experts perform complex procedures automatically, without consciously attending to specific steps (Anderson, 1987; Duchastel, 1990). Novices, on the other hand, are inclined to perform complex procedures one step at a time, without looking ahead or considering the overall problem setting. The first issue, then, is to determine if this generalization about novice-expert differences holds true in the domain of instructional design. An extensive study of expert and novice instructional designers indicates that this generalization is indeed true (Rowland, 1992). Moreover, experts tend to proceed from the problem statement (e.g., design instruction to support a particular set of instructional objectives with regard to some content area) to a framework which is likely to be appropriate for the task at hand based on past experience (Rowland, 1992). In other words, experts begin with a case construct that is known to be effective and they then modify that case-based framework to accommodate the particular details of the new task.

Novices, on the other hand, are inclined to follow procedures which are codified in sets of instructions commonly referred to as instructional systems development (ISD). The Department of Defense (DoD) is probably the largest single user of ISD. The Air Force has recently devoted significant resources to updating these procedures to reflect current academic thinking about instructional design (Tennyson, 1993). ISD is intended to provide instructional design guidelines, among other things. The intent is not to prescribe specific steps to be followed inflexibly no matter what the situation. However, these guidelines are placed in the hands of novice instructional designers who have no other recourse other than following the specific steps specified in the various ISD procedures. The results of instruction designed in these circumstances is not always optimal. When the instruction is computer-based, this process can result in expensive but ineffective courseware. Because the DoD is facing financial and personnel cutbacks, the shortage of instructional design expertise is expected to worsen while requirements for high quality courseware increase.

In response to this situation, Armstrong Laboratory has been studying various means of enhancing the performance of novice courseware developers. The basic premise is that the Air Force cannot afford to contract out the development of the courseware needed to maintain operational proficiency and readiness. Therefore, performance support tools must be provided to enable novice but motivated courseware developers to perform as if they had years of experience. Gagné proposed a relatively simple solution to this problem: Provide novices with easily understood high level guidance along with completely worked examples and they will perform as if they were advanced apprentices (1991). Gagné further proposed that the appropriate high level guidance could be constructed around the nine events of instruction (1985). The completely worked examples should reflect frequently encountered instructional objectives, such as identifying a part of a device or carrying out a test procedure on a device. Figure 1 is a screen from GAIDA which illustrates the nine events of instruction. Figure 2 shows the instructional objectives currently supported in GAIDA.



What is GAIDA?

GAIDA - Guided Approach to Instructional Design Advising

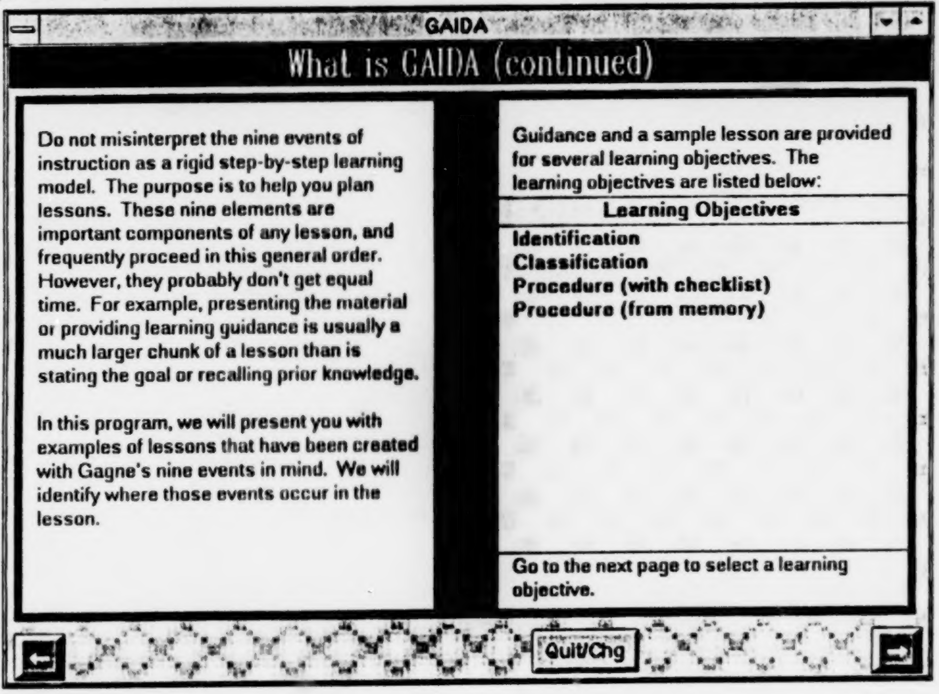
GAIDA is a PC program providing guidance for creating effective computer-based instruction (CBI). The program is based on Professor Robert M. Gagne's ideas *[1]*. GAIDA guides a novice instructional designer through the steps needed to produce quality CBI *[2]*.

The guidance consists of Gagne's nine events of instruction. The events of the lesson occur roughly in order as follows, although the order is not considered inviolable:

The Nine Events of Instruction

1. **Gain attention.**
2. **Describe the goal.**
3. **Stimulate recall of prior knowledge.**
4. **Present the material to be learned.**
5. **Provide guidance for learning.**
6. **Elicit performance.**
7. **Provide informative feedback.**
8. **Assess performance.**
9. **Enhance retention and transfer.**

Figure 1. GAIDA's nine events of instruction.



What is GAIDA (continued)

Do not misinterpret the nine events of instruction as a rigid step-by-step learning model. The purpose is to help you plan lessons. These nine elements are important components of any lesson, and frequently proceed in this general order. However, they probably don't get equal time. For example, presenting the material or providing learning guidance is usually a much larger chunk of a lesson than is stating the goal or recalling prior knowledge.

In this program, we will present you with examples of lessons that have been created with Gagne's nine events in mind. We will identify where those events occur in the lesson.

Guidance and a sample lesson are provided for several learning objectives. The learning objectives are listed below:

Learning Objectives

Identification
Classification
Procedure (with checklist)
Procedure (from memory)

Go to the next page to select a learning objective.

Figure 2. GAIDA instructional objectives.

In summary, the theoretical framework for GAIDA is drawn from two sources. From cognitive science, GAIDA proceeds on the assumption that providing novices with on-line examples or cases will make up a significant portion of the difference between novice and expert instructional design performance. From instructional science, GAIDA proceeds on the assumption that elaborating the nine events of instruction will provide an easily understood and meaningful framework for a novice designer (for additional elaboration of integrating theoretical frameworks, see Gagné & Merrill, 1990; see also Spector, Polson, & Muraida, 1993).

Implementation of an Instructional Design Advisor

Armstrong Laboratory decided to test Gagné's hypothesis. Gagné agreed to come to the laboratory as a National Research Council Senior Fellow and design the system that he had proposed. Gagné argued that GAIDA should first attempt to support a difficult design task, such as training students to memorize a complicated procedure. The School of Aerospace Medicine at Brooks Air Force Base provided such a case: a procedure to test a patient's respiratory capacity. Students have to learn how to set up a device called a spirometer, how to connect a patient to the device, what to tell the patient to do, and how to interpret the graph produced by the machine. The sample computer-based lesson and the accompanying design guidance were created under the close supervision of Gagné and a subject matter expert (SME). The original system was coded in Asymetrix' ToolBook (a high level, object-oriented language for the MicroSoft Windows environment on 80386/80486 personal computers). Because GAIDA was itself a piece of instruction, Gagné wanted to include an opportunity for users (novice developers) to practice applying the guidance provided. This necessitated allowing users to create a new ToolBook lesson. This task of providing an opportunity for practice proved to be a distraction. Users were not familiar with ToolBook and were not motivated to learn it since they would be using another authoring language.

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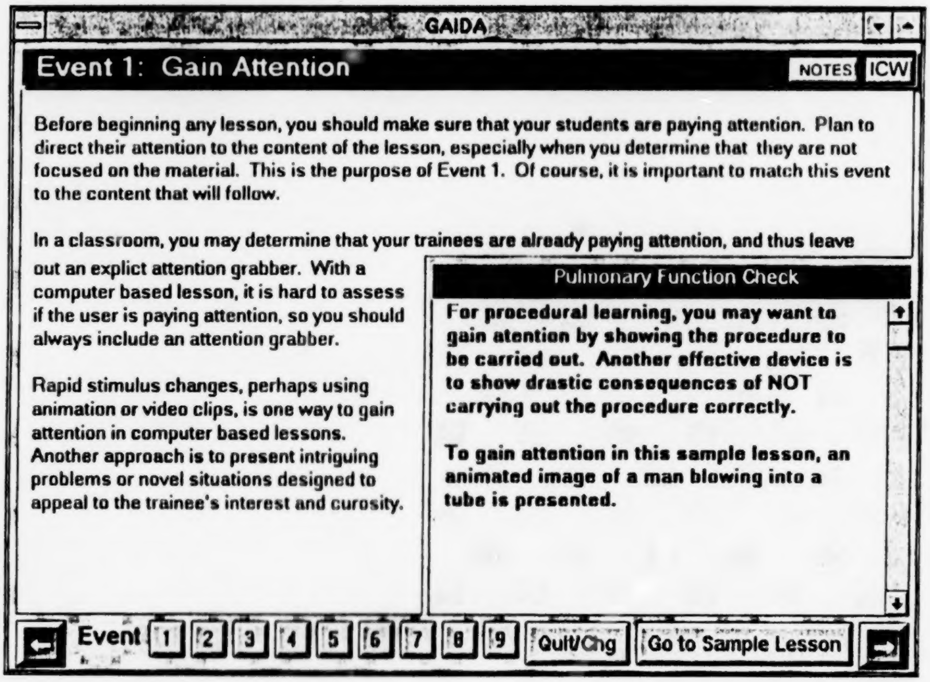
The GAIDA design team eventually dropped that requirement, which meant that the subsequent GAIDA version was more like on-line tutorials provided with many software packages. The revised version with a checklist procedure was then tested at an Air Force Technical Training Center with six instructional designers. The results were positive in that all users indicated that the guidance was useful and instructive and could be applied to their design tasks and implemented in the various languages they had available (Gagné, 1992).

Figure 3 depicts the general architecture that has been adopted for GAIDA. Once the user has selected a case thought to be similar to the development task at hand, that lesson is loaded into memory and the elaboration of the nine events continues. The outer window provides a generic explanation of what it means to gain a learner's attention. There is additional guidance for those using multimedia which is provided via the "ICW" (interactive courseware) button. The "notes" button allows users to keep notes that could be used as a draft storyboard. The inner window provides first a generic view of what could be done in this type of lesson and then a textual description of what was done. The user can put the system into case-mode by pressing the "SAMPLE LESSON" button.



Event 1: Gain Attention

Before beginning any lesson, you should make sure that your students are paying attention. Plan to direct their attention to the content of the lesson, especially when you determine that they are not focused on the material. This is the purpose of Event 1. Of course, it is important to match this event to the content that will follow.

In a classroom, you may determine that your trainees are already paying attention, and thus leave out an explict attention grabber. With a computer based lesson, it is hard to assess if the user is paying attention, so you should always include an attention grabber.

Rapid stimulus changes, perhaps using animation or video clips, is one way to gain attention in computer based lessons. Another approach is to present intriguing problems or novel situations designed to appeal to the trainee's interest and curosity.

Pulmonary Function Check

For procedural learning, you may want to gain atention by showing the procedure to be carried out. Another effective device is to show drastic consequences of NOT carrying out the procedure correctly.

To gain attention in this sample lesson, an animated image of a man blowing into a tube is presented.

Figure 3. GAIDA event elaboration.

Figure 4 depicts the case-mode, which is a part of the actual lesson. GAIDA can be executed entirely in case or lesson mode so that users can view exactly what students see. The expected mode of use is guidance mode, with the opportunity to view the lesson directly as desired. Figure 4 actually shows a text screen from the lesson that comes up after an animated sequence of a patient breathing into the spirometer. One of the hypotheses that we are testing is the utility of providing the on-line capability of switching back and forth between a lesson/student view and a guidance/designer view. Data collected to date from more than 40 users indicate that this mode switching feature is one of the most frequently used features in GAIDA. In fact, it is used more than the note-taking capability which is a bit of a surprise.

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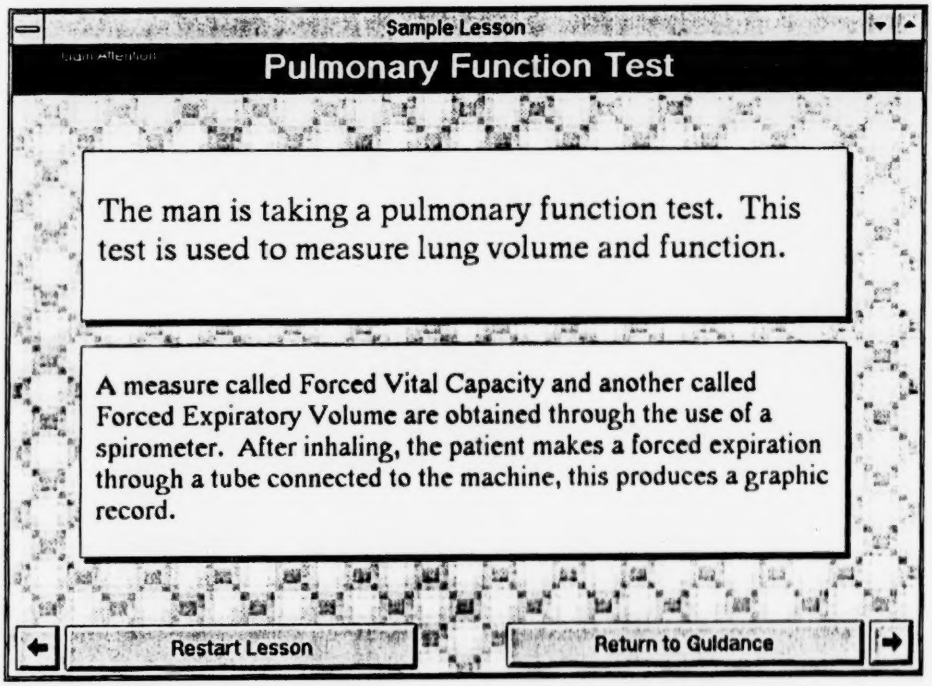

The man is taking a pulmonary function test. This test is used to measure lung volume and function.

A measure called Forced Vital Capacity and another called Forced Expiratory Volume are obtained through the use of a spirometer. After inhaling, the patient makes a forced expiration through a tube connected to the machine, this produces a graphic record.

Figure 4. GAIDA case mode (lesson view).

Two additional cases were added after the procedural cases were refined in order to provide a minimum repertoire of cases to support a novice courseware designer (see Figure 2). At this point, the GAIDA architecture has stabilized and GAIDA is now easily extensible. New example cases can be added as they are validated and become available. The guidance which elaborates the nine events and the specific cases can easily be changed to accommodate specific practices at various sites. In short, GAIDA is well positioned to grow into a much more robust on-line design advisor with an elaborate case base. Four additional cases are now under development which will extend GAIDA's domain of applicability into academic subject matter as well as into advanced multimedia (digital audio and video).

Evaluation of an Instructional Design Advisor

The evaluation of GAIDA has revealed a number of interesting findings: (1) users were confused by a completely open hypermedia tutorial on ISD tested in conjunction with the first GAIDA version; (2) users were able to follow and benefit from the structured (restricted movement) hypermedia approached incorporated in GAIDA; (3) controlled studies of novice instructional designers (SMEs in this case) showed that courseware developed using GAIDA's guidance was generally effective and superior to that developed without the benefit of this guidance (Gagné, 1992).

It is worth noting that evaluation of an automated instructional design advisor is somewhat complicated. First, there must be an appropriate set of evaluations for the courseware produced using a performance support tool such as GAIDA. That is to say that the lessons and courses must be instructionally effective and appropriate measures must be established to document this fact. However, the primary focus is not on the instructional intervention between learning environment and learner,. as in traditional evaluations. The primary focus in on the intervention between the novice designer and the automated instructional design

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tool. These interventions must be evaluated with regard to cost-effectiveness (Did they help novices produce effective instruction in less time than some baseline standard?). The system must also be evaluated with regard to instructional utility (Was the system helpful in creating meaningful interactions for learners and did it help advance the novice into a more expert-like state with regard to instructional design?). These are not simple questions and we do not pretend to have the answers. We can say that our evaluations are continuing so that we can better address such questions.

Conclusions

Our conclusions are that: (1) the content of the revised ISD model is useful; (2) the practice of following that model is time-confusing and stifling; (3) on-line instructional design cases are useful to novice designers; and (4) restricted hypermedia systems are appropriate for introducing novice designers to the complexities of instructional design. We believe that as additional cases are added to the GAIDA case base along with the appropriate instructional commentaries that it will be possible to accelerate the performance of novice courseware developers so that they will perform as advanced apprentices. The potential cost savings of this kind of performance enhancement are enormous.

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Learning Organizations in the Knowledge Society: Practical Perspectives on Knowledge and Knowledge Transfers

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Abstract: The present knowledge society places challenging learning requirements on all organizations. A generic example of knowledge scripting and profiling in a customer service organization is introduced. The example proceeds to analyze the hidden knowledge-intensive activities and associated concept hierarchy that underlies the design of knowledge transfer from experts to points-of-use. Aspects of dividing knowledge between workers and support systems are discussed and some roles of computer-based educational systems in the transfer process are identified.

In the Knowledge Society Learning Is More Important than Ever Before

We have entered the knowledge society -- although we do not yet know the full implications (Böhme et al, 1986; Senge, 1990; Wiig, 1991; Drucker, 1993). However, we know that a larger percentage of our working population than at any earlier time are knowledge workers -- much over 50%. These workers are increasingly engaged in sophisticated knowledge-intensive activities. We see that the quality of their work products and services increases, although -- because of ubiquitous competition -- these improvements often do not command noticeable increases in prices. These are indications of desirable societal progress -- as we normally think of it. However, as a consequence, everyone in society is constantly asked to "do more with less."

On the individual level, the increased requirements for knowledge workers to handle more sophisticated knowledge-intensive activities result in needs for greater competency and expertise -- Greater knowledge. To respond to these needs, we must prepare workers to a greater extent than ever before. They need to learn more.

On the organizational level, the increased requirements lead to aconstant need for all organizations to change. As Garratt states: "For any organization to survive and have a chance of growing, its rate of learning has to be equal to, or greater than, the rate of change in its external environment!" (Garratt, 1990)

In the knowledge society learning organizations must acquire knowledge on two levels. First, they need to learn to perpetually redesign their products, services, and business processes to provide acceptable deliverables to the market place at reasonable prices. Second, organizations need to transfer sufficient knowledge to their workforce so all can act intelligently and competently and perform the required knowledge-intensive tasks proficiently -- with ease and satisfaction.

What Can the Learning Organization Do?
A Challenging Scenario -- Transfer Knowledge from Expert Areas to Points-of-Use

A large service firm has a central pool of experts. They work with difficult customer-related issues. These experts also develop new perspectives, judgments, and approaches to deal with problems and they work with outside experts to continually improve available knowledge. They are responsible for supporting customer representatives in over a hundred field locations whenever difficult situations occur. Over time, as the organization grew, this led to thousands of daily telephone calls and e-mail messages, most of which would not be required if the field reps were provided with appropriate knowledge. Unfortunately, the experts' ability to help has often been hampered by not having as complete information as the fields reps. Overall, the need to refer to the central experts has been disruptive to customers and very costly -- it is not desirable at all.

To improve customer service and reduce costs, the firm decides to transfer as much knowledge as practical from the central experts to the field reps. The reps are well trained in the basics of their work and the major questions are to determine how the additional knowledge they need can best be transferred to them.

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The firm undertakes in-depth analyses of the knowledge-intensive scripts and activities for the most important (most frequent and highest value-added) tasks. These analyses identify the knowledge required to perform competently. The results determine the knowledge reps need to possess in their minds and the knowledge that can be provided by computer-based or other support systems. The resulting knowledge transfer program includes several modes: education (rather than training), knowledge-based and conventional decision support systems, and several reference documents -- some paper-based and others available in electronic form. Some of the less frequent and more difficult situations still need referral to the central expert pool which has been reduced as many of the experts are transferred to demanding positions elsewhere. The pool now also assumes greater responsibility for benchmarking and building new knowledge where that is required.

Some Aspects of the Learning Organization

The example in the above scenario is typical of organizations that wish to learn actively. As outlined below, these organizations focus their top management's interest on long-term business implications of having better knowledge. To them, knowledge becomes one of the most important competitive tools they have.

The learning organization in the above scenario is proactive. Its management agrees that the organization needs to manage knowledge effectively and be clear about how knowledge is built, managed, and used. It considers the business implications expected from good knowledge management. Management particularly focuses on both first and higher order benefits and costs. It conducts in-depth qualitative impact analyses to ascertain that it decides to do the right things. Frequently, such cost-benefit analyses are based upon senior management's perceptions and beliefs and good business sense rather than on strict quantitative analyses of first-order tangible effects.

To understand and communicate knowledge-related mechanisms, management has adopted several models. The "knowledge creation wheel" (Figure 1) is a working explanation of the basic knowledge building and value-adding process. Management plans for the organization to continuously build its knowledge base and has adopted the "knowledge spiral" (Figure 2) as its representation for this concept (Ikujiro, 1991). As a measure of how fast the organization learns, it is in the process of identifying representative cycle times for new concepts and knowledge to emerge, be perfected (built), organized, and put to practical use to create value-added.

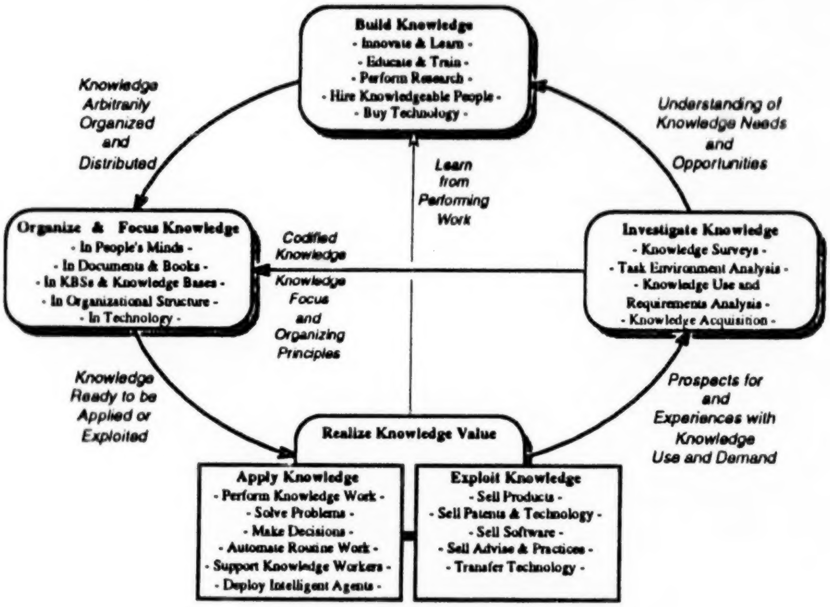
Build Knowledge
- Innovate & Learn -
- Educate & Train -
- Perform Research -
- Hire Knowledgeable People -
- Buy Technology -
Knowledge Arbitrarily Organized and Distributed
Understanding of Knowledge Needs and Opportunities
Learn from Performing Work
Organize & Focus Knowledge
- In People's Minds -
- In Documents & Books -
- In KBSs & Knowledge Bases -
- In Organizational Structure -
- In Technology -
Codified Knowledge
Knowledge Focus and Organizing Principles
Investigate Knowledge
- Knowledge Surveys -
- Task Environment Analysis -
- Knowledge Use and Requirements Analysis -
- Knowledge Acquisition -
Knowledge Ready to be Applied or Exploited
Prospects for and Experiences with Knowledge Use and Demand
Realize Knowledge Value
Apply Knowledge
- Perform Knowledge Work -
- Solve Problems -
- Make Decisions -
- Automate Routine Work -
- Support Knowledge Workers -
- Deploy Intelligent Agents -
Exploit Knowledge
- Sell Products -
- Sell Patents & Technology -
- Sell Software -
- Sell Advise & Practices -
- Transfer Technology -

Figure 1. The Basic Knowledge Creation Wheel.

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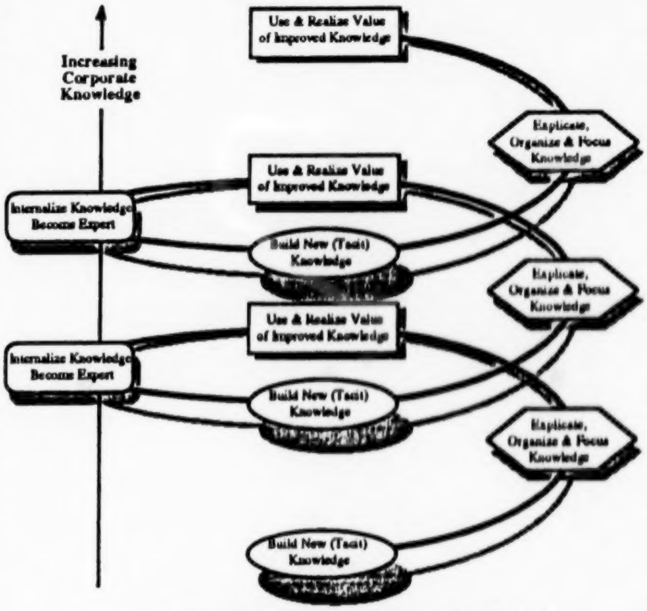
Increasing
Corporate
Knowledge
Use & Realize Value of Improved Knowledge
Explicate, Organize & Focus Knowledge
Use & Realize Value of Improved Knowledge
Internalize Knowledge Become Expert
Build New (Tacit) Knowledge
Explicate, Organize & Focus Knowledge
Use & Realize Value of Improved Knowledge
Internalize Knowledge Become Expert
Build New (Tacit) Knowledge
Explicate, Organize & Focus Knowledge
Build New (Tacit) Knowledge

Figure 2. Progressing Up the Knowledge Spiral.

These broad concepts provide a beginning understanding of some underlying mechanisms. Management realizes that it needs to identify actual sources and handlers of knowledge as it is transferred to the points of use. In particular, it is important to identify where knowledge resides in the different transfer stages and who is responsible for the different functions. For that purpose, a high level knowledge flow model (Figure 3) with more than 30 flows has been identified.

For transferring knowledge to the customer service representatives in the field, five different knowledge sources were identified as is shown Figure 3. Three separate functions were identified to be responsible for compiling and transforming the knowledge to be transferred. The existing "training" department has obtained additional responsibilities to develop and deliver modern "educational" programs. A new, separate, multi-disciplinary entity has been created in partnership with Human Resources, Training, and Management Information Systems. It is responsible for knowledge acquisition and analysis, and for organization, compilation, and validation to ascertain that the knowledge base is properly represented, well structured, and contains only acceptable facts, concepts and perspectives, judgments, and approaches.

Dissemination of knowledge is performed by five separate functions as indicated in Figure 3. Each of these has many different knowledge transfer modes at their disposition. The modes are chosen based on the particular requirements of the types of knowledge and the way work is performed at the points-of-use. For example, some rarely needed and relatively simple conceptual knowledge is delivered to the field as part of paper-based manuals in addition to having been treated in the computer-based educational system. Frequently needed and more complicated knowledge is taught in the form of concepts and principles while some of the related details are provided through computer-based knowledge-based support systems.

Detailed Analysis of Knowledge-Intensive Work

The knowledge required to deliver quality work is analyzed by knowledge scripting and work function profiling (Wiig, 1993). Content for knowledge analysis is acquired through interviews, expert and average worker observations, and simulations where novices perform real-life tasks assisted by experts. Scripts with knowledge-intensive steps are identified for specific major tasks and are summarized as in Figure 4. All steps may not be required for each task, and different tasks may require execution of steps in different sequences depending upon the actual situation and the worker's associations and routines for what to do next. Knowledge-intensive activities for each step are identified and the knowledge needed to perform them proficiently is made explicit. As part of this work, major concept hierarchies (see Figure 5) are elicited from the experts to identify the conceptual basis for mental processing and judgments.

A major observation by many who have previous experience in "requirement analysis" is that most of the knowledge-intensive activities performed by competent workers are hidden from view and not visible or observable by the casual onlooker. It requires considerable expertise to discern and identify these activities and determine their content and function. It is invariably discovered that experts perform many activities very quickly -- almost automatically -- compared with less competent workers. The quality of the experts' work is also often much better as a result of comprehensive understanding and judgment.

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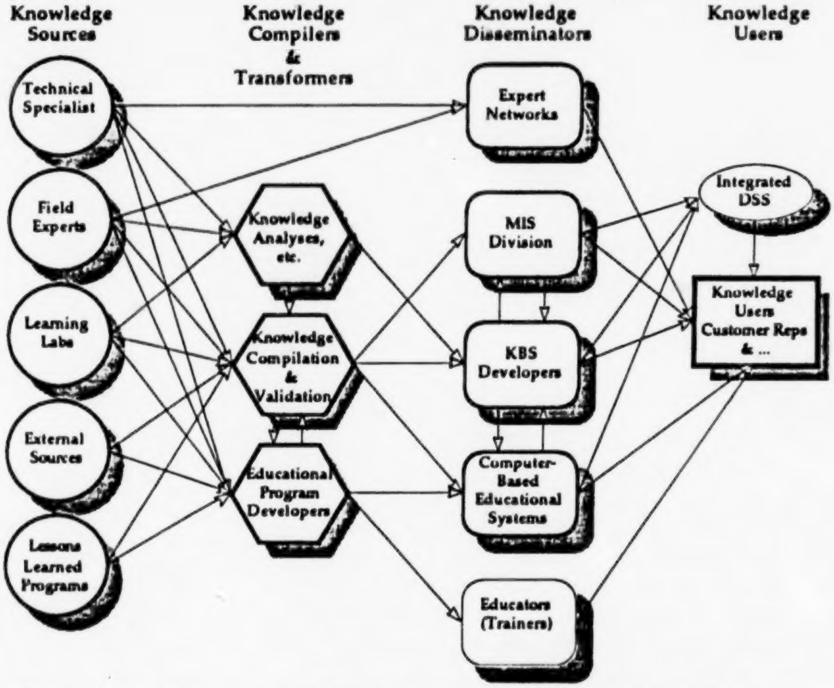
Knowledge Sources
Knowledge Compilers & Transformers
Knowledge Disseminators
Knowledge Users
Technical Specialist
Field Experts
Learning Labs
External Sources
Lessons Learned Programs
Knowledge Analyses, etc.
Knowledge Compilation & Validation
Educational Program Developers
Expert Networks
MIS Division
KBS Developers
Computer-Based Educational Systems
Educators (Trainers)
Integrated DSS
Knowledge Users Customer Reps & ...

Figure 3. Examples of Internal Knowledge Flows in the Knowledge Organization.

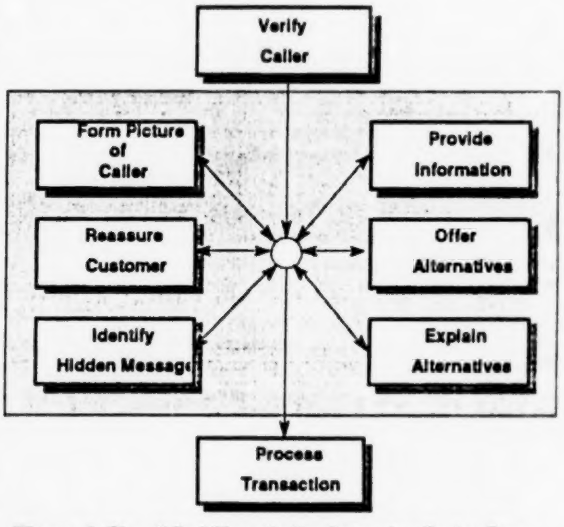
Verify Caller
Form Picture of Caller
Provide Information
Reassure Customer
Offer Alternatives
Identify Hidden Message
Explain Alternatives
Process Transaction

Figure 4. Simplified Knowledge-Intensive Script Steps.

When we deal with in-depth knowledge and understanding and requirements for performing knowledge-intensive work, we need to understand that we must distinguish between knowledge at different conceptual levels. They are: (1) Goal-setting or idealistic knowledge; (2) Systematic knowledge; (3) Pragmatic knowledge; and (4) Automatic knowledge. These conceptual levels reflect the degree to which we have internalized the knowledge and how we apply it to the situations we face. We often have intuitive comprehension of goal-setting knowledge but use it to direct our thinking and activities. We have deeper comprehension of systematic knowledge and use it to understand "how the world works." We use pragmatic knowledge to make conscious decisions. Automatic knowledge we have internalized to the point that we use it without thinking. We must also distinguish between knowledge of different types: (1) Factual knowledge; (2) Conceptual knowledge; (3) Expectational (judgmental) knowledge; and (4) Methodological knowledge (Wiig, 1993).

The Knowledge, Skills, and Personal Characteristics Profiles

Scripting and profiling lead to knowledge, skills, and personal characteristics profiles. The profiles are developed in two ways: (1) From the specific knowledge components that are identified as part of the knowledge

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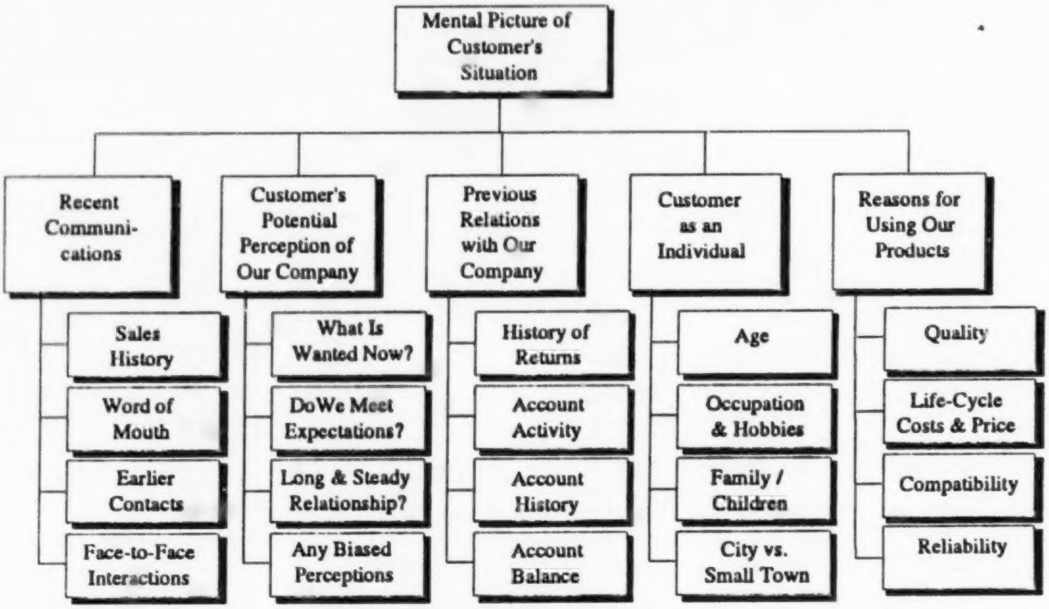
analysis; and (2) From in-depth discussions with experts, managers, and others who have professional insights into what is required to deliver quality work in the target function. Profiles for the example scenario are presented in Figure 6. They are used to portray the proficiencies that are required -- or that individuals might actually have. Gaps are readily identified to guide development of educational programs or determine where individuals or groups may benefit from knowledge transfer.

The **knowledge profile** denotes the different areas of in-depth knowledge and understanding that are needed to deliver quality work and that can be developed through education or other modes of knowledge transfer that facilitate deep learning. The **skills profile** denotes particular skills that individuals need to work competently and which may be improved by training. The **personal characteristics profile** denotes those personal qualities that are required. The latter characteristics often cannot be easily changed.


Mental Picture of Customer's Situation
Recent Communi-cations
Sales History
Word of Mouth
Earlier Contacts
Face-to-Face Interactions
Customer's Potential Perception of Our Company
What Is Wanted Now?
DoWe Meet Expectations?
Long & Steady Relationship?
Any Biased Perceptions
Previous Relations with Our Company
History of Returns
Account Activity
Account History
Account Balance
Customer as an Individual
Age
Occupation & Hobbies
Family / Children
City vs. Small Town
Reasons for Using Our Products
Quality
Life-Cycle Costs & Price
Compatibility
Reliability

- Gauge knowledge level of customer.
- Figure out product use pattern.
- What products and services make sense for this customer?
- Determine (by making assumptions) customer intent.

Figure 5. Concept Hierarchy for Developing the Mental Picture of the Customer's Situation.

Teaching Concepts Instead of Training Facts Provides Many Benefits

Concept hierarchies are central to identifying the details of knowledge required for competent work. In customer service situations we find that there are several top-level concepts such as "Mental Picture of Customer Situation," "Customer's Intent," and given these, "The Best Way of Helping Customers."

In forming top-level concepts, workers build abstract, often qualitative, mental models. They assess the state of the concept by use of discrete qualitative brackets such as: "The customer's situation is not serious but competent technical help is required to correct the problem." To form broad concepts, they "chunk" lower-level concepts to combine simpler concepts into more comprehensive mental models. Chunking often varies between individuals and may reflect misunderstandings or different associations (Wiig, 1993).

It has been found to be relatively easy to teach concepts to people at all ages. Strong foundations can be provided to make it possible for learners to build understandings and judgments quickly and accurately. Teaching workers the foundations of underlying concepts reduces requirements for providing much of the detailed factual knowledge as has often been the tradition. Instead of teaching details for all products, it is possible to educate

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workers in the conceptual principles accompanied with representative details to show how the abstract schemas and scripts translate into concrete conditions. The bulk of details can then be provided via such modes as computer-based support systems. Models exist for effective teaching of broad concepts and schemas while connecting them firmly to concrete and detailed examples. Such models suggests frequent switching between concrete cases and the underlying concepts and theory (Wiig & Freedman, 1993, Wiig, 1993). Transfer of knowledge is quicker, can be performed with less errors and misconceptions, and provides greater insights and flexibility when it focuses on transferring the underlying concepts populated with samples of representative factual knowledge.

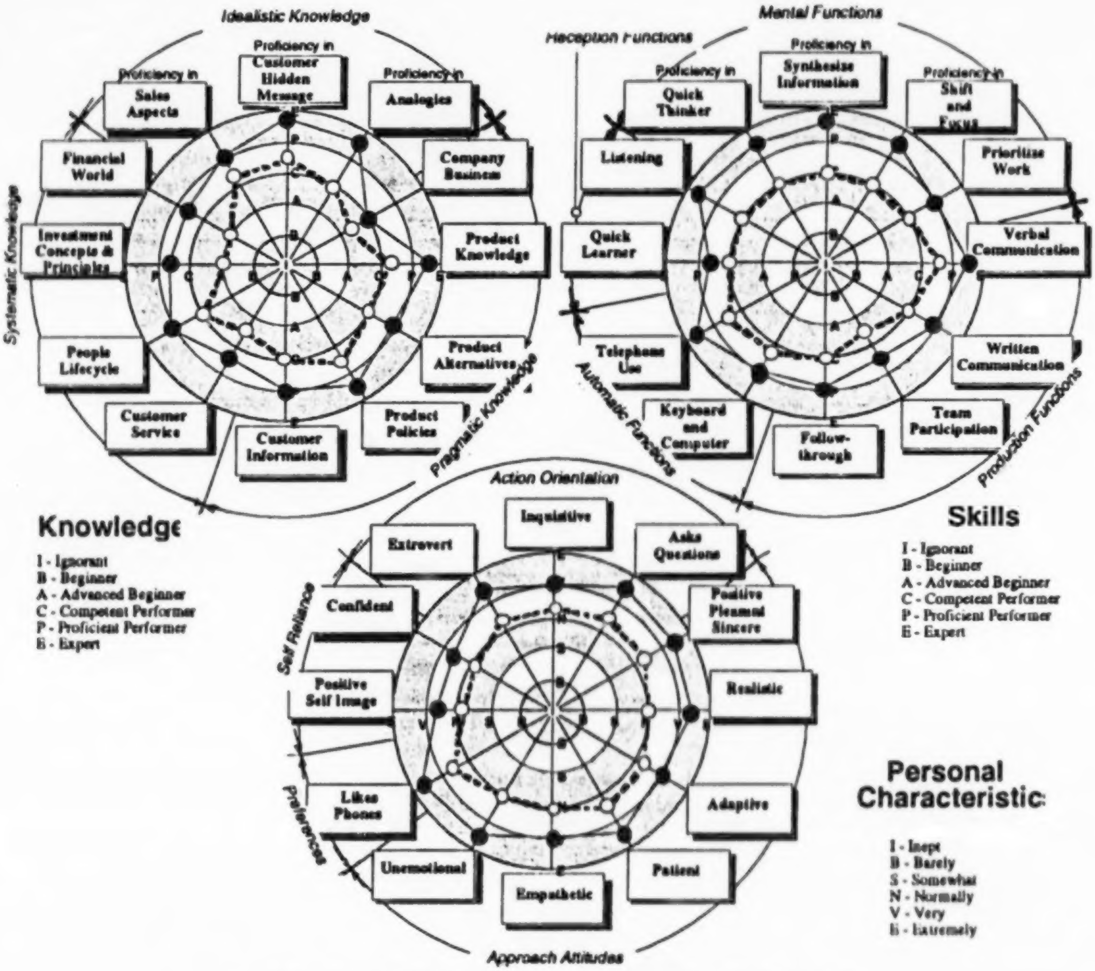
Idealistic Knowledge
Proficiency in
Customer Hidden Message
Proficiency in
Sales Aspects
Proficiency in
Analogies
Financial World
Company Business
Investment Concepts & Principles
Product Knowledge
People Lifecycle
Product Alternatives
Customer Service
Customer Information
Product Policies
Systematic Knowledge
Pragmatic Knowledge
Knowledge
I - Ignorant
B - Beginner
A - Advanced Beginner
C - Competent Performer
P - Proficient Performer
E - Expert
Reception Functions
Mental Functions
Proficiency in
Synthesize Information
Proficiency in
Quick Thinker
Proficiency in
Shift and Focus
Listening
Prioritize Work
Quick Learner
Verbal Communication
Telephone Use
Written Communication
Keyboard and Computer
Follow-through
Team Participation
Automatic Functions
Production Functions
Skills
I - Ignorant
B - Beginner
A - Advanced Beginner
C - Competent Performer
P - Proficient Performer
E - Expert
Action Orientation
Inquisitive
Extrovert
Asks Questions
Confident
Positive Pleasant Sincere
Positive Self Image
Realistic
Likes Phones
Adaptive
Unemotional
Empathetic
Patient
Self Reliance
Preferences
Approach Attitudes
Personal Characteristics
I - Inept
B - Barely
S - Somewhat
N - Normally
V - Very
E - Extremely

Figure 6. Knowledge, Skills, and Personal Characteristics Profiles.

What Can the Computer Know and What Must the Human Know?

Knowledge workers who provide customer service often find themselves in time-critical situations that require that they "think on their feet." They engage in customer dialogs and verbal problem solving where the subject matter may span large domains. It is generally impossible to have these individuals possess all the factual, conceptual, judgmental, and methodological knowledge they need to have available to perform their routine and non-routine tasks. In most situations, the amount of knowledge -- particularly factual knowledge -- required exceeds the mental capacity of the average knowledge worker. However, as indicated above, it is quite manageable to provide the workers with selected knowledge that will allow them to function competently without possessing it all.

The challenge is to provide these individuals with knowledge and a work environment that allow them to at all times: (1) Understand the situations they encounter; (2) Plan where they wish to direct the situations; and (3) Have the security that they will be able to obtain whatever additional knowledge, facts, or information they will need to proceed.

We often have the option to provide knowledge workers in these situations with powerful computer-based support systems to assist them. When this is an option we are immediately faced with the issue, "What can the computer know and what must the human know?"

One solution is for the computer to have all factual knowledge and also have as much methodological, conceptual, and judgmental knowledge as is practical. That knowledge may be represented in an active reasoning system, or less desirably, in a sophisticated but passive query system such as hyper-media. The human should be provided with as much conceptual knowledge as possible to understand all general principles that underlie the situations s/he is expected to deal with. In addition, s/he must know how the factual knowledge relates to the concepts and how to apply all methods. The particulars of the methods can be obtained from the support system when required. Particulars of judgment and other specifics may also be obtained from the support system as needed.

This division of knowledge has many advantages. Educational requirements can be kept to a minimum. Workers can be more versatile and flexible and can change jobs as required. Volatile knowledge may be incorporated into the support system whenever it changes.

Designing Knowledge Transfer Programs

Knowledge transfer programs must be designed with great care to complement the organization they will serve. There are numerous knowledge transfer mode options and many of these are very effective and sophisticated but may require considerable infrastructure. As computer-based multi-media delivery vehicles are reduced in price, it makes great sense to consider these as part of the delivery process. On the other hand, human interactions, networking, and teaming are (still) very important and need to be considered for many important knowledge flows.

Computer-Based Educational System Roles in the Knowledge Transfer Process

Transferring knowledge from its sources to points-of-use proves very valuable -- but also very difficult and costly. It is always expensive to elicit, organize, and structure knowledge in computer-based systems. However, when that is done, it becomes inexpensive to deploy it. The up-front costs of teacher-delivered knowledge is often negligible but in large organizations the cost of providing personal one-to-many education can be excessive. Other factors must also be considered. Personal real-time education may interfere with working schedules and may involve costly travels whereas computer-based systems may provide highly flexible time management opportunities.

Designing computer-based educational systems may be quite different from designing conventional computer-based training systems (Helander, 1988). The knowledge acquisition required to elicit and organize knowledge requires higher specialization and is costlier. The design of these systems appears to be more a function of the particular knowledge. It is not a standard approach. In spite of these difficulties, modern knowledge transfer is already highly dependent upon computer-based educational systems and, as our expertise increases, they will become more important.

Another opportunity for computer-based education relates to the fact that we occasionally find that some high-performance knowledge has a very short half-life and needs to be refreshed through games, simulation, or other means. Computer-based educational systems, resident in workstations, are found to be very useful for this purpose.

Concluding Perspectives

Learning organizations need to become expert at building and transferring knowledge from its source to points-of-use. They need to learn to deal with knowledge management and analysis in greater detail than most now are prepared to do, and they need to have technical expertise to staff all knowledge management-related functions in the process.

When considering how knowledge should be managed, it is imperative that senior management's perspectives of how and where the business should go drives the process. It is similarly important that considerations for potential value-added contributions from knowledge management actions be considered, given senior management's visions for higher order market reactions and such notions as what it means to deliver quality products and services into the market place.

For a learning organization to be successful in these efforts, it is a requirement that the organization's culture and incentives are changed to facilitate and promote all the activities that need to become second nature for all within the organization. That refers to the need to learn at every opportunity, as well as the need to share knowledge with others. It is clear that if the culture and incentives support the separate contributions of individuals -- rather than team efforts or the overall organization -- there will be little motivation for experts to share their knowledge with others.

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Trends in Instructional Technology: Educational Reform and Electronic Performance Support Systems

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Abstract: As a result of [the society] moving into the information age, changes in the educational process as well in the workplace are inevitable. Parents, students, school officials and business leaders are currently experiencing the effects of the information explosion era on a daily basis. Upgrades and new releases of computer hardware and software are occurring almost before we can fully understand our old systems. Are decision makers ready to make the changes necessary to prepare students with the competency and foundation skills (as identified by the Secretary's Commission on Achieving Necessary Skills) that they will need for the changing workplace? This paper will address two trends in the instructional technology field: reforming the educational process and implementing electronic performance support systems into the workplace. These trends are important because they have influence on moving the teaching and learning process to a new evolutionary stage.

As society approaches the 21st century, technology will play an important role in the lives of adults as well as in the lives of children. Business leaders, school officials, parents, and students need to be aware of the impact technological change will have on the educational system as well as on business and industry (Secretary's Commission on Achieving Necessary Skills [SCANS], 1991). Furthermore, with markets becoming more global and companies desperately striving to stay ahead, jobs of the future will demand more highly skilled employees (Naisbitt, & Aburdene, 1985; SCANS, 1991; Work Force 2000, 1988). During the coming years, jobs that require skills with information-processing technology will be of the norm rather than a rarity (Naisbitt & Aburdene, 1991). To prepare students for a work force that is different from their parents Reigeluth (1992) argues that the educational system requires moving from an industrial age model towards an information-age model that views the educational process as the integration of learning tasks, with the teacher as a coach or facilitator using electronic technologies as tools within the classroom.

The mastery of reading, writing and arithmetic will no longer be enough to propel students to success in the work place. According to the SCANS (1991) report, researchers identified five competency skill areas and three foundation skill areas that are necessary for success in the workplace. The five competency skills, as defined by SCANS (1991) are:

1. Resources: Identifies, organizes, plans, and allocates resources,
2. Interpersonal: Works with others,
3. Information: Acquires and uses information,
4. Systems: Understands complex interrelationships and,
5. Technology: Works with a variety of technologies.

In addition, included in the SCANS (1991) report is a description of the three-part foundation skill requirement. They are:

1. Basic Skills: Reads, writes, performs arithmetic and mathematical operations, listens and speaks,
2. Thinking Skills: Thinks creatively, makes decisions, solves problems, knows how to learn and
3. Personal Quality Skills: Displays responsibility, self-esteem, sociability, self-management, integrity and honesty.

Will high school or college graduates be able to master the competency and foundation skills upon graduation? This question focuses on how society is changing and as a result the needs of students who are preparing to enter the workforce have changed.

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> Education is our passport to the future, for tomorrow belongs to the people who prepare for it today.
>
> Malcolm X

Educators are seeking new ways to ensure that students have the appropriate skills on a local and national level. On the local level, school officials are re-thinking the design of schools for the information age (Molenda, 1992; Reigeluth, 1987) and on the national level the Bush administration announced America 2000, a new education strategy, designed to provide national educational goals for the nation's schools (Eley, Foley, Freedman & Scheel, 1992). The fundamental purpose for these initiatives is to empower students to tackle the challenges facing them in "the real-world".

Employees can no longer believe in job security (Naisbitt & Aburdene, 1985) or that a college degree alone (without constantly upgrading ones' skills) will propel him or her in the workplace. Employment for many people, currently and in the future, requires a commitment (whether embraced by the employee or imposed by the employer) to change and life-long learning. Naisbitt and Aburdene (1985) argue that "in the new information society where the only constant is change, we can no longer expect to get an education and be done with it. There is not one education, no one skill, that lasts a lifetime now" (p. 141). Furthermore, Packer (1988) argues that if the U.S. economy is to stay competitive, "twenty-five million American workers will need to upgrade their basic skills during the 1990's" (p. 8). This is a low estimate when taking into account the bases for projections are only on the changing mix of jobs and do not include workers who need to upgrade their skills as a result of new technology (Packer, 1988).

Nevertheless, will graduates be ready to face a world that is constantly changing at a rapid pace? There was a time when a clerical employee learned how to type and file and would not have to learn a new procedure for years- if ever. However, today the replacement of a word processor occurs almost as often as the assignment of a new manager. Many times, in response to receiving this new software application, the employee must become proficient without a decrease in productivity. This situation places the employee in the position of seeking the quickest and "least painful" method of training.

By keeping abreast of the changes in society as well as in education and training, instructional technology professionals can play a key role in restructuring the educational system from its current industrial model to a system that reflects the information age. In addition, restructuring that includes integrating electronic technology into the educational system can be one solution for bridging the skill gap from high school or college to the workplace. This restructuring movement can also be the catalyst for using electronic technology as a tool to assist the teacher in developing the competency and basic skills as defined by the SCANS (1991) report. Furthermore, to bridge the skill gap for employees accessing new information, employers are investigating electronic performance support systems (EPSS) which is a computer-based tool designed to assist the employed with on-demand training and support.

The implementation of EPSS in the work place and the restructuring of the educational system are two important trends in the instructional technology field (Eley et al., 1992; Seels, 1993). These trends are important because they represent moving the teaching and learning process in our schools and on-the-job to a new evolutionary stage.

A Proactive Mindset to Change

Systematic Change Process

Change, whether planned or chaotic, brings on stress and anxiety. Moreover, unplanned change combined with minimum involvement from the people affected by the change, produces resistance (Burke, 1982). Furthermore, Burke (1982) argues that "what people resist is not change but loss, or the possibility of loss" (p. 52). This loss is generally one of two kinds: loss of the known and tried or loss of personal choice (Burke, 1982). Rickleman and Henk (1989) argue that change does not have to be unsettling if everyone involved take a proactive stand.

> By taking a proactive stand, we shift from asking "What is going to happen to us in the future?" to "What can we do to create the kind of future we want?" (Rickleman & Henk, 1989, p. 175).

Kurt Lewin, a psychologist and educator, was one of the earlier researchers to take a proactive stance for change. Lewin argued that a key principle to organizational change is a three-phase change process "unfreezing, moving, and refreezing." In trying to imagine the phases required for change Lewin used the metaphor of melting ice. Unfreezing means reducing the negative forces through new or disconfirming information, which is the function of diagnosis. Changes in attitude, values, structure, feelings, and behavior incorporate the moving stage and refreezing means reaching a new status quo with support mechanisms to maintain the desired behavior (Weisbord, 1987).

Many systematic change models have evolved from Lewin's model of change (Burke, 82). A key issue with Lewin's model is the involvement of everyone associated with the process. In addition, Lewin states "people are likely to modify their own behavior when they participate in problem analysis and solution and more important they are likely to carry out decisions they have helped to make" (Weisbord, 1987, p. 89).

Educational reform is a hot topic in the school system as well as in all levels of government. Recently, the reform movement has been shifting from a disjointed incremental effort towards more of a Gestalt perspective, where the focus of change is on the whole educational system (Bagley & Hunter 1992; Campoy, 1992; David, 1991; Pearlman, 1989; Raywid 1990; Sheingold, 1991).

David (1991) argues that "restructuring presumes the goal for educational system is not simply to catch up to the world, it needs the capacity to continue to evolve as the world continues its rapid pace of change" (p. 77). To reach this goal Reigeluth (1992) identifies "Ernest Boyer (1983), John Goodlad (1984), Theodore Sizer (1984), Lewis Pearlman (1987), Ann Lieberman and Lynne Miller (1990), Albert Shanker (1990) and Banathy (1991, 1992)" (p. 1) as advocates for systemic change in education. Reigeluth (1992) further argues that true educational reform has occurred only once in our nation's history- when the industrial assembly-line model, which is currently in place today, replaced the one-room schoolhouse. This paper will not address all the issues associated with restructuring the school. However, the author will focus on a small portion of the educational reform movement that considers integrating electronic technology into the classroom and the uses of EPSS as a tool for promoting training and support in education or business and industry work settings.

Integrating Technology into the Educational Process

Restructuring the educational system is not an easy task. It can be a very complicated and long term project yet, the results of reform can be fruitful and enriching especially if decision makers do not view electronic hardware and software as the sole answer for entrenched ills. A decision maker who believes integrating computer-based technology (into the school system) requires simply supplying teachers and students with additional new hardware and software is focusing on a "device-driven" learning environment versus a "student-centered" environment. Bagley and Hunter (1992) cited Rockman who cautions "policy makers against 'technohype', which he describes as the efforts by advocates and vendors to sell technology as the one and only answer to restructuring the school system" (p. 22). Sheingold (1991) further argues that "computer-based technology has been brought into schools during the past decade largely because the technology was seen as important in and of itself-because it was an increasingly central component of the world of adult work" (p. 77). Technology is more than just electronic devices. Eley et al. (1992) define technology as applying scientific principles to solve practical problems- a process that deals with problem solving. This definition decreases the emphasis from specific devices and places it on solving the problem (Wager, 1993). For example instructional design and teaching and learning methodologies fit the definition of technologies, however they are forgotten examples. The author suggests that the lessening of "technohype" can occur by informing decision makers that electronic technology is "a systematic blend of people, materials, methods and machines" (Eley et al., 1992, p. 27).

More important, the integration of computer-based technology into the educational process requires decision-makers to re-think their opinions on several topics- for example their views on:

1. The role of the teacher in the classroom as well as their views on teaching and learning,
2. The organization of student desks and computers in the classroom,
3. The life-cycle and maintenance of computer hardware and software.

In addition Collins (1991) identified, from the literature and observations in schools where teachers are using computers, several major trends on how computer technologies have an affect on the classroom. First, Collins (1991) argues that the role of the teacher will move from a lecturer to a facilitator and coach who actively engages students in long-term computer projects. These projects may simulate relevant "real-world" problems, where students are actively participating in arriving at solutions.

The classroom will shift from desks placed in rows where the whole class participates to desk arranged in small groups. This new classroom arrangement, along with the teacher's encouragement, can provide an environment where students can focus on cooperation and collaboration. Lastly, the author suggests that by exposing students to electronic technology used as a tool or resource for the teacher students will have an opportunity to practice the foundation and competency skills as describe by SCANS (1991).

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Sheingold (1991) provides several recommendations that may assist in the change process that includes integrating computer technology. They are as follows:

1. Bring technology and learning to the same 'table' when restructuring is being planned,
2. Reconsider how technology is organized in the district and finally,
3. Work towards teacher expertise in using a critical mass of technology.

Instructional technologists are also facing issues on how to support employees, such as teachers, administrators and business managers, when many school systems, universities and businesses are facing huge budget cuts and downsizing efforts. As a result of these changes, employees are being called upon to "do more with less" and decision makers are looking towards instructional technologists to investigate ways electronic technologies can increase productivity with a leaner workplace and fewer people available for employee support.

Currently, employees may receive their formal training off-the-job in instructor-led courses or by computer-mediated training (interactive video, computer-based training, or a combination of both), however, when the employee returns to the actual job, training and support may consist of human interaction, non-centralized reference manuals or company documentation. Problems arise when employees need specialized training but none is available until several weeks or months later. Uncertainties in the employee's ability also arise when he or she is trying to complete an assignment and need specific support but receive either too much information, conflicting information or no information at all (Brechlin & Rossett, 1991).

Employers can no longer ignore employee training. Decision makers are slowly realizing that training is a factor in ensuring that the workforce is productive. It is only after the elimination of training programs that decision makers sometimes realize its importance.

> "Training is like rowing against the current. Once you stop you are dragged downstream."
> Jozef M.M. Ritzen

As a result of these problems, decision makers are entertaining the idea of providing employees with software applications that provide immediate support and on-the-job training (OJT) from the employee's desktop computer at the specific moment of need.

The development of electronic performance support systems (an integrated electronic system that provides training and support at the moment of need for the employee) is a trend in instructional technology that can bring training and employee support to the desktop computer. In addition, with the introduction and advancements of tools such as: relational and multimedia databases, computer-based training, expert systems and on-line references, the foundation for developing electronic performance support systems (EPSS) is in place.

What is an EPSS?

Since the recent introduction of EPSS into business and industry, leaders in the field are still trying to develop a working definition associated with this tool. Raybould (1990) describes an EPSS as a "computer-based system that improves worker productivity by providing on-the-job access to integrated information advice and learning experiences" (p. 4). Whereas Gery (1991), a leader in the field of EPSS, defines an EPSS as "an umbrella concept that includes any of a variety of performance support interventions delivered on computer to the worker on the job at the time of need" (Clark, 1992, p. 36).

In describing an EPSS there are two major areas to consider, the content and the components of the system. To identify the contents of an EPSS, Gery (1991) uses the term "Infobase" which is the collection of information the employee will inquire into, access, or have presented to him or her when accessing the system. For example, the information located in a text relational database, multimedia database, expert system or on-line reference system are the type of data the employee could select from within an infobase. When manipulating the infobase, the user interacts with the components of the EPSS that can include the following:

> A range of support mechanisms and software tools including an advisory system to help in instructing or executing tasks and decision making, commercially available software programs, organizational specific application software, special purpose software utilities built especially for use within the EPSS and other interactive capabilities (Gery, 1991, p. 42).

Components of a complex EPSS can, ideally, include a combination of hypermedia databases, expert systems, modular interactive training, a dynamic maintenance system, as well as other interactive software support applications, whereas, a basic EPSS may include only a database and an on-line help system (Geber, 1991).

The common feature found in both a basic and complex EPSS is the ability of the application to provide information to the user at the moment of need (Scales & Yang, 1993).

EPSS in Educational Process

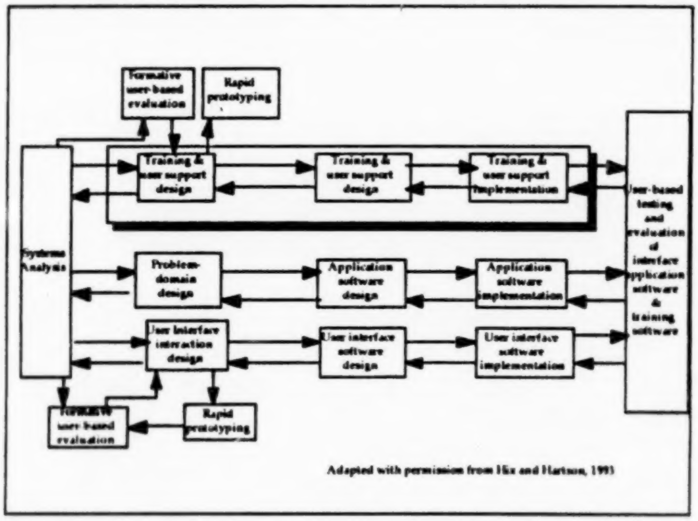
Researchers are investigating and developing EPSS and other support tools in academia as a way to increase productivity in the workplace. Merrill (1993), Gustafson (1993), and Dick, (1993) are advocates for increasing productivity as a result of decreasing the instructional development time by using an EPSS. Educators from Florida state looks towards an EPSS to increase productivity by providing an integrated information and learning system for staff involved in special education. This project is part of Florida State School year 2000 initiative (Huestia, 1993). In the mist of companies as well as academia downsizing employees are being called upon to "do more with less". To assist employees with this change EPSS are being designed to bridge the training and support gap.

Decision makers who are not ready to invest in an EPSS, may consider embedded interactive training, as a solution for some OJT needs. Embedded training, as defined by Andrews (1991), is the integration of multimedia training applications into a workplace tool. EPSS and embedded training applications are moving the training from out of a classroom onto the employee's desktop computer. In to prepare for the coming changes in workplace training, managers, software developers and instructional designers, will be faced with seeking a clearer understanding of the EPSS development process. More specifically, decision makers must addressing the issue of moving the development of training from the end to an earlier software development stage. Therefore, EPSS or an embedded training application will change the way they receive training on-the-job. In addition, individuals involved in developing software must work together in re-thinking how to incorporate the development of training applications as part of the initial software development process.

Changes in Software Development Process

In order to take full advantage of trends such as the computer-base training component of an EPSS, or embedded training, changes in the software development process are necessary. Traditionally the development of training and support documentation have not been an integrated part of the software development process. Howell (1992) provides a summary of six methods used for general software development projects. Of these six techniques, none address training and support as part of the development process. However, advances in computer hardware and software technology have made it possible to integrate embedded training and support within the software development process before the completion of the project.

The author suggests that to effectively develop the training component of an EPSS, embedded training or even non electronic support materials, the traditional software engineering model should be modified. Figure 1. displays a software engineering model that accommodates the parallel development of the application software process, user interface process, and has been modified to incorporate the parallel development of training and


Formative user-based evaluation
Rapid prototyping
Systems Analysis
Training & user support design
Training & user support design
Training & user support implementation
User-based testing and evaluation of interface application software & training software
Problem-domain design
Application software design
Application software implementation
User interface interaction design
User interface software design
User interface software implementation
Formative user-based evaluation
Rapid prototyping

Adapted with permission from Hix and Hartson, 1993

Figure 1. Software development model with training & support

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user support materials. This abbreviated software development model is one way to displays a general diagram of each of the three development processes. It is important to note that throughout each process efficient and effective communication must occur between each development group. By moving the training and support process from the end of the software development process the user will be able to test a final system complete with training and support materials. In addition, this is one suggestion of a software development model for an EPSS. Furthermore, this change would incorporate the price of training in the overall cost of the system whereby eliminating the purchase of training as an afterthought or as part of the software bundle that is "nice to have".

Summary

Educational reform and the development of EPSS are occurring as the result of the changes in the skills and knowledge needed for the workplace today. Moreover, the implementation of educational reform and EPSS in instructional technology will require following a systematic change process that looks at the entire organization for change and not just single components. Restructuring the educational system is not an easy task therefore it requires advocates for change committed to an on-going and sometimes difficult process. Any advocate for systematic change in education must first question him or herself on their views of teaching and learning and the role of electronic technology in the classroom. Having an advocate for change who is uniformed could potentially promote technology as a cure all versus as a tool for supporting teachers in their teaching and learning process. More important, to successfully integrate computer hardware and software into the teaching and learning practice, advocates for change must prepare teachers and administrators not in just "how" the computer works but also in how the teacher and student can learn "with" the compute using it as a tool or a resource. This concept calls for a change in the role of the teacher, classroom structure and social structure.

Instructional technologists are also being called upon to develop EPSS. The idea of supporting an employee with information, advice and training at their specific moment of need is attractive to employers who are seeking to increase productivity in the mist of downsizing and budget cuts. However EPSS is not a cure all solution for every training situation and does not necessarily mean eliminating additional training before or after using the system.

Lastly, our society has moved from the industrial era to the information and service age. Decision makers, whether in the work place or academia, will require involvement from their entire organization to prepare our future graduates with the appropriate skills for a changing society. Are business leaders, school officials, parents, and students, ready for this challenge?

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Electronic Performance Support Systems: Cognitive "Training Wheels" for the Acquisition of Skilled Performance

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Abstract: A cognitive rationale is proposed for the utilization of electronic performance support systems (EPSS) to aid in human information processing, thereby increasing levels of skilled performance. Current cognitive theory in the areas of attention and memory is reviewed to describe how skilled performance is developed and maintained in a performance-oriented context. Three types of performance limitations and their respective cognitive explanations are described to elucidate the information processing limitations inherent in real performance contexts: (1) Performance requiring large amounts of factual knowledge (high demands on long-term memory); (2) Performance requiring proficiency of skills infrequently utilized on the job (high demands on declarative and procedural knowledge that was never adequately processed or that decayed); and (3) Performance requiring simultaneous processing of large amounts of information (high demands placed on a limited capacity working memory). A performance intervention technique in the form of an EPSS is provided for each limitation.

Suppose you are a new employee in the customer support department of a software manufacturer. You have just received over 100 hours of training including role-playing in a simulated performance environment to help prepare you for the myriad of possible questions you will encounter once on the job. Not only are you expected to demonstrate competency, perhaps even proficiency, within a few weeks in the many areas of customer support, but you are also expected to quickly adapt to rapidly changing software specifications. Even if you have acquired the declarative knowledge (factual knowledge) and procedural knowledge (knowledge about "how" to perform the task), you may be required to process too much information at one time to perform skillfully. This is considered an overload of working memory, the temporary and limited-capacity memory store where it is believed information processing takes place (Baddeley, 1986; Klapp, 1987; Miller, 1956). Another performance limitation may be that you were adequately trained to perform a particular skill, however, the skill may be required so infrequently that the skill decays. If human performance increases in almost any cognitive skill with the amount of consistent practice of that skill (Schneider & Fisk, 1982), then it should be reasonable to ask the following question: How could enough practice possibly be provided in prior training to develop competent skills for the large variety of problem-solving situations that employees will face?

There are some practitioners in the performance technology industry that suggest that the types of performance problems mentioned above are not the result of inadequate training, but rather the result of using an old training "paradigm" in a new business climate (Geber, 1990; Gery, 1991). The old training paradigm prescribed the development and implementation of training programs if employees did not have the required knowledge and skills to perform adequately. A new business climate is emerging that is causing performance technologists to question the value of this approach to performance problems for several reasons. First, products and services are changing more rapidly today than ever before. Employees must keep up with constantly changing information if they are to remain competent and if their employers are going to remain competitive. As a result they must receive training much more frequently than before. Secondly, employees are being more frequently placed into jobs for which they were not adequately trained. This is a result of the need for businesses to fill positions more quickly to survive in highly competitive markets. Finally, businesses are being required to operate with a more diverse work force. Businesses are experiencing a growing need for being able to train a workforce varying in educational, cultural, and socio-economic backgrounds.

What Gloria Gery (1991) and others in the performance technology industry have called for to meet these challenges is a new paradigm that expands the arsenal of performance intervention techniques to include innovative approaches to old and new training problems. In her book, *Electronic Performance Support*

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System, Gery (1991) outlines the major "paradigm shifts" required of performance technologists for the successful adoption of these new techniques. At the heart of this paradigm shift is the movement away from thinking that all training must take place as a formal training event to a realization that training is an on-going process and is most meaningful when it occurs in the context of performing the task.

One technique is to offer employees training in the time of need, in the right amount, and in the right form to compensate for the knowledge gaps and skill deficiencies believed to be responsible for performance problems. This technique is commonly referred to as performance support. According to many proponents (Geber, 1990; Gery, 1991), performance support embraces the notion of learner-centered instruction, one of the essential principles of adult learning theory. Moreover, learners must be involved in their learning if they are ever to develop competency.

Competency is usually viewed as having the necessary knowledge, skill, or experience for some purpose. Highly competitive organizations, like the software manufacturer that must compete with other manufacturers in the area of support service to survive market demands, need support personnel that are more than just competent. They need personnel that are proficient. Proficiency goes beyond mere competency in that proficiency demands that an employee function as an expert. While a competent employee has the suitable knowledge, skills, and experience to perform a majority of the tasks at an adequate level and in a sufficient time frame, the proficient employee has a vast repertoire of knowledge and refined skills that can be executed with relative ease. This level of expertise is the central goal of this new paradigm that seeks to provide employees with the necessary tools to function at this level with minimal prior knowledge, skill training, and experience.

The new tool integral to the success of this approach is what has been coined by Gery (1991) and others as an Electronic Performance Support System (EPSS). In its most basic form, an electronic performance support system (EPSS) is a computer-based performance tool consisting of an informational data base, an advisory system, and a tutorial/learning base composed of granular-sized pieces of computer-based training all linked to one another in a relational data base. With the help of an integrated graphical user interface (GUI) and a few clicks on a pointing device, the user can access a rich variety of media on a number of topics. Most EPSS's use a hypermedia system that allows the user to create their own path to any number of topics delivered by a combination of text, graphics, animation, audio and/or video. The chief operating function or characteristic of this system that allows the user (i.e., employee) to solve problems due to a lack of prior knowledge, experience, or training is the ability to quickly access well-structured pieces of information, advice, and tutorial assistance just at the moment of need as determined by the user in the context of the present performance problem. It is this type of consistent, easily accessible, user-oriented support that advocates (Geber, 1990; Gery, 1991; Raybould, 1991) claim to be the key to this new technique to enhancing human performance.

The purpose of this paper is to draw from current cognitive theory to describe how skilled performance is developed and maintained in a performance-oriented context. Skilled performance is the application of knowledge and skills required to adequately perform a variety of related tasks in their context. Three types of performance limitations will be discussed and analyzed from a cognitive perspective to uncover the human information processing limitations that are responsible for inadequate performance. These three performance limitations and their associated cognitive explanations are listed in Figure 1.

Performance Limitation	Cognitive Explanation
1. Performance requiring large amounts of factual knowledge	1. High demands on long-term memory without adequate processing
2. Performance requiring proficiency of skills infrequently utilized on the [illegible]	2. High demands on declarative and procedural knowledge that was never adequately processed or that decayed
3. Performance requiring simultaneous processing of a large amount of information	3. High demands placed on a limited capacity working memory

Figure 1. Performance Limitations and Cognitive Explanations

The extant cognitive literature in the areas of attention and memory relating to the development and maintenance of cognitive skills will be examined. A theoretical framework based on this research will be provided for discussing how electronic performance support systems can be utilized to aid human information processing and thus increase levels of skilled performance in the contexts of the three performance limitations outlined above.

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The Development of Skilled Performance

Much has been written describing the various stages of cognitive skill acquisition (Anderson, 1982; Newell & Rosenbloom, 1981; Schneider & Fisk, 1983). Fitts (1964) stated that skill learning occurs in three stages: (1) a cognitive stage, in which a description of the procedure is learned; (2) an associative stage, in which a method for performing the skill is worked out; and (3) an autonomous stage, in which the skill becomes more and more rapid and automatic. In analyzing each one of these stages, Anderson's ACT (Adaptive Control of Thought) model (Anderson, 1983) will be used to trace the development of skilled performance in each of these three stages. Attention and memory theory will be discussed within the framework of an information processing model to demonstrate the critical role each of these cognitive components plays in determining the rate and level of skilled performance acquisition.

The Cognitive Stage

In the cognitive stage the learner is involved in the process of acquiring what Anderson (1982) calls declarative knowledge. Declarative knowledge can be viewed as a set of facts that pertain to a particular skill. In the case of our customer support representative this would include such facts as how much memory does the software program need to operate, the necessary steps involved in installing the application, visual images of how various computer screens look, and other types of factual knowledge relevant to operating the software. This knowledge is still flexible and not committed to how it will be used (Anderson, 1987).

In Anderson's ACT model, declarative knowledge is what makes up the component known as declarative memory. In the context of our scenario, this is the store for factual information and rules about the software and how to support customers. In the old paradigm there is an attempt to teach as much of this information as possible to the learner in hope that they will retain enough information to perform well once on the job. The new paradigm attempts to provide this information "along the way" as the learner (employee) encounters the need for it. In this approach the learner is able to make connections between the information and the context in which it will be used (Harmon & King, 1979). Anderson draws a distinction between declarative knowledge and what he refers to as procedural knowledge. Declarative knowledge is knowing "that" about a domain whereas procedural knowledge is knowing "how". Both of these types of knowledge are important in the development of skilled performance. Procedural knowledge in the customer service representative example would be knowledge about how to convert a document from an old software version to a new software version. The old training paradigm would prescribe that the learner receive enough practice in the training program to recall the necessary steps involved in the procedure. At best, the old paradigm might offer an enormous reference manual that contained a step-by-step procedure. The new paradigm suggests that the procedural knowledge must be applied consistently in the context of the performance problem for skilled performance to be acquired. This is consistent with the evidence found by researchers (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Chase & Ericsson, 1982; Schneider & Fisk, 1983) that suggested that increases in human performance on a task depends on the amount of consistent practice of that task.

In learning how to trouble-shoot (e.g., analyze a problem, eliminate improbable causes, formulate a solution) customers' problems in our scenario of the customer service representative, possessing a great deal of factual information (both declarative and procedural) may have direct relevance to actual performance (Annett, 1991). This would appear to be in contrast to the new paradigm prescription previously mentioned. However, it is in the term "possessing" (rather than acquiring) that is significant in understanding the uniqueness of this approach. An electronic performance support system can serve as a an extension of long-term memory for declarative and procedural knowledge necessary for solving a variety of problems. The representative can quickly access both types of information while also receiving expert advice from a coach. The coach's advice is context-specific and integrated into the infobase. The representative is able to practice using the EPSS to help trouble-shoot customers' problems while not suffering in the cognitive stage from a lack of knowledge -- declarative or procedural.

To understand how other performance limitations are created during skilled performance acquisition and how they can be mediated by EPSS's, a model of human information processing is helpful in describing how information is perceived, encoded, stored, and retrieved. This paper is primarily concerned with processing limitations due to the roles and limitations of attention and memory in performing complex, cognitive tasks. In Atkinson and Shiffrin's (1968) model of the human information processing system there are three types of memory components called the sensory memory, short-term memory, and long-term memory. Another term used to refer to a component of the memory system is working memory. Working memory has been traditionally thought of as the part of the memory system where active information processing takes place -- analogous to a mental scratch pad (Baddeley, 1986). Working memory is limited in its capacity to process

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information as it must switch between various control mechanisms. Some of these mechanisms which are crucial to carrying out a task are controlling perceptual attention to various input stimuli, selecting memory strategies to facilitate short-term and long-term memory requirements, and selecting, modifying, and executing problem solving strategies. The term short-term memory is sometimes used interchangeably for the term working memory. For the purposes of this paper, the term working memory will refer to both the area where active processing takes place as well as the limited-capacity storage place for items of information held for processing.

There are two types of working memory processing limits: (1) limited capacity and; (2) duration. Limited capacity is the amount of information (number of individual units of information) a person can maintain in their working memory at one time. Miller (1956) determined that the average capacity for holding to-be-remembered items in this memory store is seven items, plus or minus two. Duration is another important aspect of working memory capacity. Duration refers to the length of time a set of information can remain active in working memory without being actively rehearsed. Peterson & Peterson (1959) demonstrated that a sequence of three consonants, well within the subject's memory span, will show precipitous forgetting over a 20 second period if the subject is prevented from rehearsing the material. These two types of processing limits can have an enormous impact on the acquisition of skilled performance as will be discussed later.

Working memory (also referred to as short-term memory) can be compared to a more permanent store for facts or propositions (Anderson, 1982) referred to as long-term memory or long-term store (LTS). This memory component is considered to be unlimited in storage capacity, however, retrieval of information is sometimes difficult. The mechanisms for retrieving information from long-term memory and the ways in which EPSS's can aid in this process will be addressed in more detail later.

All knowledge in the ACT theory starts out in declarative form as individual propositions. A proposition is a basic unit of meaning that expresses a simple relationship or idea between two concepts. An example of a proposition for the customer service representative would be "a floppy is a disk". The representative's knowledge of the software, the computer, and all of the other related information acquired in training are stored in memory as an interrelated network of propositions, connected by linking pathways, and accessed by means of spreading activation. Spreading activation is a theoretical process by which one proposition activates another in its pathway as determined by its strength in relationship to the retrieval cue.

The way in which each one of these components works can be demonstrated in a scenario involving our customer support representative. A customer asks the representative how to select his\her new printer for current use. The question is received in the sensory register (in this case the auditory register) and deposited into the limited-capacity working memory. Once here, probe cues are generated to activate propositions in the long-term memory related to the probe cue. In this cognitive stage, the novice representative is searching for links among propositions in declarative knowledge, or in the declarative memory component (Anderson, 1983). The answer is a series of steps (propositions) that together make up a procedure. Contextual information already in working memory concerning the problem is also encoded in the probe cue. The probe search can be viewed as a series of cycles (Shiffrin, 1970): (1) generate probe information and place it into working memory; (2) use the probe information, along with the general contextual information presently in working memory, to activate associated information from long-term memory; (3) scan the search set and choose some relevant information for appropriate decision making; (4) decide whether the appropriate information has been found and whether the search is over. The success of retrieving the correct information from long-term memory relies on a variety of factors. The probe cue is made up of probe information generated by the representative as well as transient information like context. The context in which the information was originally stored is of primary importance in determine retrieval success. If, for example, the trainer made a particular reference to a mnemonic device for remembering the steps, such as a word whose letters stood for each step, the link to that information in long-term memory may be activated by hearing or seeing that word. Efficient retrieval will occur when the transient context in working memory at the moment of test has not changed considerably from that during storage. This of course depends on the knowledge base and structure of the customer service representative. A novice has fewer associative links to the missing information than does an expert. Also, practice helps to strengthen the pathway between propositions resulting in faster and more accurate retrieval rates (Anderson, 1987). Providing access to retrieval cues and thus enhancing long-term memory retrieval is one way in which electronic performance support systems can help to improve performance. This technique will be discussed in more detail later.

Attentional limitations and working memory limitations also affect performance during the cognitive stage. Unlike the expert who can perform many functions simultaneously because some steps have already become automatized (converted to procedural knowledge), the novice in this stage must actively rehearse the information concerning the problem in working memory while also attending to other incoming stimuli. Working memory represents the working space in which thinking and decision making takes place. Because it

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has a limited-capacity to hold information temporarily for processing (Miller, 1956) and be actively involved in processing information, the more stimuli that it must attend to the less resources it has available for carrying out the task. The more competition between processing resources the longer it will take to generate a solution, if at all. As the customer service representative (CSR) progresses into the associative and automatization stages of development, more and more of these resources are freed up because of the transition from controlled to automatic processing.

In the cognitive stage, much of the processing that is done is considered to be controlled processing. This type of processing is characterized as a slow, generally serial, effortful, capacity limited, subject controlled processing mode that must be used to deal with novel or inconsistent information compared to automatic processing which is fast, parallel, effortless, not limited by working memory capacity, not under direct subject control, and performs well developed skilled behaviors (Schneider & Shiffrin, 1977; Schneider & Fisk, 1983). Information relevant to the task must be rehearsed to keep it from decaying while at the same time control mechanisms are operating in working memory to search for a solution.

Two aspects of attention theory (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) are operating in this situation: (1) distraction; and (2) limited-capacity. Distraction is the result of divided attention due to attempts at parallel processing. During controlled processing this can impede performance because the novice CSR does not have the repertoire of automatic skills that the expert CSR has developed in the automatization phase. Chase & Simon (1973) have witnessed this in experiments with novice and expert chess players. The expert chess players are able to focus on higher-level skills than the novice due to superior memory for sequence of moves and memory for familiar patterns.

This limited-capacity aspect is implicit in the explanation of distraction. If only a limited amount of resources can be utilized effectively at one time, then the more a CSR can accomplish with automatic processing, the more he\she will have available for memory consumptive controlled processing. This progression from controlled to automatic processing helps to alleviate the processing limitations characteristic to learning to perform novel tasks.

The Associative Stage

The second stage of the development of skilled performance is the associative stage. In this stage declarative knowledge is compiled into sets of procedural knowledge called productions. Anderson (1987) refers to this process as knowledge compilation. This is the crucial step in developing domain-specific skill. According to Anderson, the learner uses what he calls weak problem-solving methods to generate productions in a new domain. Weak methods include the use of analogy, means-ends analysis, and pure forward search. These methods help the learner interpret the declarative knowledge and give it meaning in a performance context. The result is a set of productions for solving problems in a particular domain.

Productions are units of knowledge in the form of conditional statements, such as IF-THEN statements, that specify the conditions required for a particular type of action. In Anderson's ACT* model this type of knowledge would make up the memory component called production memory. During this stage errors in previous performance are detected and eliminated making the productions more efficient in reaching the goal. In the ACT* model information in working memory must match a production in the production memory for it to trigger a production response. In the case of the CSR learning how to handle a common customer request, such as converting a document from an old software version to a new version, the CSR using a production system (a group of productions) for this problem can now concentrate on problem solving strategies and decision making. Part of the compilation process is the elimination of the need to hold declarative information in working memory for interpretation, rather, that information is built into the proceduralized production (Anderson, 1987). The CSR does not have to spend processing resources trying to remember each step of the procedure and can instead concentrate on anticipating the users questions. Before the proceduralization develops the CSR should experience declarative interference between performing the skill and remembering similar declarative knowledge, but this content-based interference should disappear when the knowledge is proceduralized (Anderson, 1987).

The production for each skill has a condition that specifies the circumstances under which the production can apply and an action that specifies what should be done when the production applies (Anderson, 1982). Both controlled and automatic processing are still required in the associative stage to solve problems. The more familiar the CSR becomes with principles and concepts in this domain, the more attentional and cognitive resources he or she will have available to use on developing automatic processing skills through practice. This stage of development shows increases in performance due to a progression from controlled, serial, effortful, limited-capacity processing to a more automatic, parallel, effortless, processing using minimal working memory resources.

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The Autonomous Stage

The third stage of skilled performance acquisition is the autonomous stage. In this stage automatic processing has developed for much of the skill. These automatic productions are shown to be relatively resource free, modular, fast, accurate, coordinated, not under direct control, and show high transfer (Schneider & Fisk, 1983). Now that much of the skill can be carried out without using working memory resources, controlled processing can be utilized to maintain strategy information, results of previous actions, and time varying information. Many of the problems associated with working memory limitations can be overcome as automatic processing becomes available.

The development of automatic processing and its relationship with controlled processing has been studied to determine the mechanisms of skilled performance (Schneider & Fisk, 1983). Automatic processes are developed only through extensive, consistent practice. Consistent practice occurs when the stimuli and responses are consistently mapped (CM), that is, across training trials the individual makes invariant overt (or covert) responses to stimuli (or classes of stimuli) (Schneider & Fisk, 1983). Research conditions where stimuli are not consistently mapped, referred to as varied mapping (VM), the subjects' performance did not improve even after thousands of trials. In detection paradigms, research has shown that extended practice at consistently attending to a subset of stimuli results in quantitative and qualitative changes in performance (Moray, 1975; Schneider & Shiffrin, 1977). Reaction times are faster, detection performance is less affected by memory load or number of channels, and performance becomes much less sensitive to attentional resource demands (Schneider & Fisk, 1982). This suggests that dual-task performance can be improved with CM training in some of the task components.

Schneider and Fisk (1983) outline a series of assumptions about automatic and controlled processing concerning the mechanisms involved in acquiring skilled performance:

1. Practice leads to the development of a large vocabulary of automatic productions which perform consistent stimulus to response transformation;
2. Practice makes automatic productions resource free, autonomous, fast, accurate, and coordinated;
3. Changing the contents of working memory can change the enabling (test) conditions that switch in different sets of productions appropriate for a given situation;
4. Practice can incorporate both internal and external context cues to enable appropriate sets of production; Both internal and external stimulus cues can cause a strategy shift which is then maintained in working memory;
5. Practice improves chunking of information about the outputs, goal states, and inputs of the situation. This chunking allows very detailed information about rapidly changing events to be maintained in a very limited working memory.

These mechanisms help distinguish automatic processing from controlled processing and further delineate their key roles in the development and maintenance of skilled performance. The rest of this paper will focus on the development of electronic performance support systems that effectively mediate between these competing mechanisms.

Performance Limitation #1 - Long-term Memory Demands

Long-term memory capacity is considered to be unlimited, although this would be very difficult to prove. The question usually of concern for increasing long-term memory performance is in providing the correct retrieval cue (Tulving & Thompson, 1973). Finding an appropriate retrieval cue to activate knowledge in long-term memory is tied to the context in which the information was originally processed in working memory (Shiffrin, 1976; Tulving & Thompson, 1973).

Another possible explanation of retrieval failure is that the level of processing was weak during the initial presentation. This could result in information never making it to long-term memory, stored too weak to access, or decayed due to insufficient processing (Craik & Lockhart, 1972;). This theory is an alternative to the information processing model previously discussed. No matter what the explanation is for long-term memory retrieval failure, there appears to be a limit to what can be expected of a trainee in a performance context.

The performance problem for consideration here is of the CSR being unable to store a vast amount of information presented to him\her in the training session. Because the trainee is involved in controlled processing during the training session, he\she is limited to the amount of information he\she can sufficiently process at one time (Navon & Gopher, 1979; Schneider & Shiffrin, 1977). There are many factors that can affect this including prior knowledge, domain complexity, amount and rate of stimuli presented, and the amount of practice available in the training session. The instructional designer of the training program may be

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able to compensate for some of these problems, but realistically, there is too much declarative knowledge involved in learning a software package to be acquired in a traditional training program.

Performance Solution #1 - Provide An Extension Of Long-Term Memory

One week into the job the CSR receives a call from a customer who needs to know which printer files are required to interface with her printer. While selecting printer files was a topic covered in the training session, the CSR did not have the opportunity to practice this skill using the customer's printer as an example. This is an example of missing declarative knowledge from long-term memory. The procedural knowledge and working memory capacity is available but without the required declarative knowledge the problem cannot be solved (at least not in any timely manner).

Luckily, the CSR's company has installed an electronic performance support system that is available at his\her terminal. By clicking on a menu button pictured as a printer icon, the CSR is immediately presented with another menu screen. This screen has a list of frequently asked questions about printers. He\she easily spots the question he\she needs, "Locating User Printer Files", and clicks on the button. Up pops a prompt asking the CSR to input the name of the user's printer. After a few key strokes or mouse clicks a new screen comes up that lists the required files for the user's printer. The CSR reads off the file names to the user and sends her on her way all in a matter of a few minutes.

What happens in this situation is that the CSR is using the EPSS as an extension of his\her long-term memory. He\she does not have to store this type of infrequently used information because the EPSS does it for him. Studies with job aids indicate that they can bridge the memory associated learning gaps that tend to expand with the complexity of equipment (Swezey & Pearlstein, 1974; Rowan, 1973; Smilie, 1977). What the CSR must develop are the productions (procedural knowledge) for using the EPSS to quickly access the information. It is reasonable to expect this skill to develop from controlled processing to automatic processing from the result of practice (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Anderson, 1987; Schneider & Fisk, 1983). The process used to solve the problem can be consistently mapped because while there are many different printers available, there is one general procedure for accessing the information using the EPSS.

This type of approach to the development of skilled performance has an explicit transfer quality about it. Valuable training time is not spent on acquiring large amounts of technical information, rather, time is spent on general problem solving skills that have a high transfer quality. Developing automatic processing skills for retrieving information from the EPSS's infobase is what is focused on in the training session. There is, of course, an amount of prior knowledge required about the software and hardware for the CSR to successfully trouble-shoot problems using the EPSS. Principles and concepts that would help guide the CSR in developing problem solving strategies and heuristics should be emphasized (Anderson, 1987).

A variation of this scenario could also support the use of EPSS's to aid in long-term memory retrieval. For example, if the CSR had encounter this same exact problem two months prior to this but could not remember the missing declarative knowledge, the EPSS could provide missing retrieval cues. The CSR may remember by just re-visiting a couple of the screens in the previous search. Even if the CSR executes the entire search process, the exercise will strengthen the automatic processing component of this skill.

Performance Limitation #2 - Infrequently Used Skills

Qualitative changes in performance occur when individuals are given extensive, consistent practice with a skill (Schneider & Fisk, 1983). An individual can progress from controlled processing to automatic processing. Automatic processing can provide many benefits for overall performance including accuracy, speed, and little demand on controlled processing resources allowing for dual-task performance (Shiffrin & Schneider, 1977). A question for performance technologists might then be, "How much practice is required to automatize a skill?". The answer is not simple or clear-cut. Many factors influence the number of trials required to automate a skill including complexity of the skill, interference from dual-task practice, and degree of consistency (Schneider & Fisk, 1982).

Unfortunately, many performance contexts do not provide adequate practice to develop automated skills. In fact, some skills may get used so infrequently that the employee may have to exert high levels of controlled processing to perform the skill. The more controlled processing involved in a skill, the less likely proficiency will be exhibited. This may be satisfactory in some performance situations, however, incompetency is not the trait that the software manufacturer wants to convey to its customers.

Performance Solution #2 - An On-Line Coach For Infrequent Tasks

The advisory component of the EPSS guides the user by providing interactive advice on how to solve problems, develop strategies, and in making decisions. This is the component of the EPSS most directly responsible for helping novices function like experts during infrequently performed tasks. An example using the CSR will help demonstrate this aspect.

The representative has just received a call from a user wanting to know how to create parallel columns in a word processing document. The representative is aware that this procedure is possible but has only performed it once six months ago in the training session. Normally, this would be a time to either drag out the reference manual and start searching for a listing of the procedure, or start calling other CSR's to find someone who knows how to perform this task. Either one of these alternatives will probably result in a time consuming process that would be perceived poorly by the customer.

With the help of the representative's EPSS, he\she can quickly access an on-line coach that has been linked to the infobase. By clicking on the button for import and then the button for coach, the representative receives prompts for information concerning the problem. After inputting the two types of documents and their manufacturer's names, the coach begins to take the representative through a step-by-step process using graphics, text, and audio segments. The representative can quickly run through the process in a few minutes while the customer is on hold. Then he\she can report back to the customer with the necessary knowledge to act like an expert.

A list of important questions may also be provided to the representative to ask the user before initiating the procedure. By inputting the customer's answers into the system, the on-line coach can provide specific tips and pointers about the customer's software or system, as well as cautions for avoiding errors. The customer does not have to know the source of this representative's demonstrated expertise.

Again, the point to be made here is that the representative is able to function as an expert with the training of a novice. The learning that is taking place is two-fold: (1) skill development in using the EPSS to solve problems and; (2) incidental learning of the procedures involved in solving the problem for the customer. As the representative's experience in using the EPSS increases, he\she will begin to build a repertoire of productions for efficiently accessing problem solving solutions built into the system. While there is currently no specific research to back up this claim, it can be hypothesized from other experiments using job aids.

Stone and Hutson (1984) investigated user selection patterns and strategies of information while using a hypertext/graphics computer-based job aiding system to perform an assembly task. The researchers found a 5% error rate with subjects using the hypertext system compared to a 100% error rate in previous studies using text only, a 91% error rate with studies using graphical information only, and a 75% error rate in studies using both text and graphics but without the rapid and organized access provided by the hypertext structure. Because the subjects (N = 20) varied in their preferences and repetitions in selecting information, the researchers concluded that when people can get the information they need when they need it, performance on procedural tasks is facilitated. But since people vary in the information they feel they need, it may be useful to have more information (and more forms of information) available than any one person is likely to need. This is accomplished while keeping the surface text uncluttered in order to avoid information overload for those who do not need that information. Booher (1978) cites Guillford (1973) as he states that considerable evidence has been accumulated in education and training research to show the advantages of using a variety of media in work environments to help workers meet performance objectives.

Incidental learning from using an electronic performance support system would be determined by the amount of controlled processing resources invested in solving the problem, as well as many other factors. According to Navon and Gopher (1979), for a given individual at a certain moment, a task is characterized by several parameters, such as sensory quality of stimuli, predictability of stimuli, availability and completeness of relevant memory codes, stimulus-response compatibility, response complexity, and amount of practice. By increasing the amount of resources invested in a task, the learner can increase the performance gain. However, since the purpose of the EPSS is to reduce the amount of resources invested in a task, it can be assumed that incidental learning will vary from task to task according to the factors previously mentioned.

Performance Limitation #3 - Overload of Working Memory

Human decision making tasks, such as those involved in command and control, require that a large amount of information be simultaneously considered and integrated into an appropriate decision (Klapp & Philipoff, 1983). Because working memory is considered to be limited in its capacity to hold information for processing (seven, plus or minus two items; Miller, 1956) and in its ability to process information while attending to other stimuli (Peterson & Peterson, 1959), tasks that require the simultaneous processing of information put a burden on this system. The way in which this burden is accommodated through controlled and automatic processing determines performance of the tasks involved.

An example of this condition using the customer support representative scenario would be a condition in which the representative is required to use controlled processing resources to search for a solution to a customer's problem while also responding to the customer's questions. This process becomes even more aggravated when the representative must also hold several pieces of declarative knowledge in working memory while involved in problem solving and decision making. To make matters worse, the declarative knowledge could be lost from working memory when a co-worker asks the representative a question about another problem.

The Performance Solution #3 - Reducing Working Memory Load

The solution to a performance problem created by an overload of working memory capacity is to create an extension of the working memory. This can be accomplished with an EPSS. In this situation the representative has been asked by the customer to trouble-shoot a problem. The problem is that the customer's document file will not print on a new type of printer. Ordinarily, the representative would have to first ask the customer a series of questions to help in the trouble-shooting process. The answers to these questions would have to be maintained in working memory while the representative attempted several problem solving strategies. The results of each attempt would also need to be maintained to facilitate the problem solving process.

Fortunately, the representative has an EPSS that was designed for this type of performance problem. Not only does the EPSS provide prompts for the series of questions, it holds the answers in memory cells on the screen so that the representative can access them at any time. The EPSS is assuming the role of the working memory in keeping the information active for processing. The advisory system of the EPSS guides the representative through the trouble shooting phase and keeps record of the progress of each attempt by asking the representative to respond to questions after each step has been executed.

By assuming these working memory functions, the EPSS frees processing resources so that he\she may effectively communicate with the customer. Other environmental distractions do not impede the progress because the EPSS is storing the necessary information and results. This level of artificial intelligence may not be available with every EPSS, however, it is easy to see how marginal attempts to reduce working memory load can increase performance.

Conclusion

This new paradigm in performance technology requires much more understanding about cognitive theory and processing limitations in a variety of performance contexts before a useful design theory can be developed for electronic performance support systems. Research is needed to determine if actual learning is taking place when the learner is not required to engage in controlled processing while solving a problem. Before proposing a study that tested some of the assumptions in this paper in performance environments supported with and without an EPSS, careful observations of people using EPSS's in context may provide the necessary insight to develop a well-structured research study.

Although the performance interventions described in this paper sound promising from a performance technology perspective, enthusiasm must be tempered with careful research. The implications of a workforce relying too much on a machine for aiding cognition could prove disastrous. Machines, especially computer-based systems, have been known to "go down". Also, motivation to perform job tasks may become depleted if it is perceived that the computer has assumed a superior role to the person using it. Nonetheless, the technology is already being used in this capacity by developers using intuition due to a lack of cognitive theory applied to this type of performance intervention technique. Perhaps as the industry support for this technique continues to grow, performance technologists and cognitive psychologists will discover the reasons why electronic performance support systems seem to enhance human performance and as a result develop better methods for designing, developing, and evaluating them.

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